

**U.S. FISH AND WILDLIFE SERVICE  
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM**

SCIENTIFIC NAME: *Rana muscosa*

COMMON NAME: Mountain yellow-legged frog, Sierra Nevada Distinct Population

LEAD REGION: Region 8

INFORMATION CURRENT AS OF: April 14, 2010

**STATUS/ACTION**

☐ Species assessment - determined we do not have sufficient information on file to support a proposal to list the species and, therefore, it was not elevated to Candidate status

☐ New candidate

☒ Continuing candidate

☐ Non-petitioned

☒ Petitioned - Date petition received: February 10, 2000

☒ 90-day positive - FR date: October 12, 2000

☒ 12-month warranted but precluded - FR date: January 16, 2003; June 25, 2007

☐ Did the petition request a reclassification of a listed species?

**FOR PETITIONED CANDIDATE SPECIES:**

a. Is listing warranted (if yes, see summary of threats below)? Yes

b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? Yes

c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded.

Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for the species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The "Progress on Revising the Lists" section of the current CNOR (<http://endangered.fws.gov/>) provides information on listing actions taken during the last 12 months.

☐ Listing priority change

Former LP:

New LP:

Date when the species first became a Candidate (as currently defined): January 16, 2003

☐ Candidate removal: Former LPN:

- ☐ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.
- ☐ U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.
- ☐ F – Range is no longer a U.S. territory.
- ☐ I – Insufficient information exists on biological vulnerability and threats to support listing.
- ☐ M – Taxon mistakenly included in past notice of review.
- ☐ N – Taxon does not meet the Act’s definition of “species.”
- ☐ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: *Amphibian, Ranidae* (true frogs)

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE: California, Nevada

CURRENT STATES/COUNTIES/TERRITORIES/COUNTRIES OF OCCURRENCE:  
California

LAND OWNERSHIP: Though the species is currently known to occur mainly on National Forest and National Park lands, the species can potentially occur elsewhere. The total acreage of potential mountain yellow-legged frog habitat in the Sierra Nevada is approximately 3.5 million ha (8.6 million ac). Of this, the total Federal land acreage is approximately 3 million ha (7.5 million ac). The USFS manages approximately 2.3 million ha (5.6 million ac) of land within the range of the mountain yellow-legged frog, including 745,500 ha (1,842,081 ac) of designated wilderness areas across 10 different National Forests.

The NPS manages a total of 629,065 ha (1,554,449 ac) of potential mountain yellow-legged frog habitat in the Sierra Nevada in four different National Parks.

Other Federal land managers within this range description of the mountain yellow-legged frog include the BLM with 83,436 ha (206,173 ac) of potential mountain yellow-legged frog habitat, the Service with 232 ha (574 ac) of potential mountain yellow-legged frog habitat (Blue Ridge National Wildlife Refuge), and the military with 19 ha (48 ac) of potential mountain yellow-legged frog habitat.

Native American lands include 8,357 ha (20,650 ac) of potential mountain yellow-legged frog habitat.

State lands (managed by the CDFG, the Department of Forestry and Fire Protection, the Department of Parks and Recreation, and the State Lands Commission) include a total of 15,087 ha (37,280 ac) of potential mountain yellow-legged frog habitat.

Lands owned and managed by water districts include 3,794 ha (9,374 ac) of potential mountain yellow-legged frog habitat. Other private lands include 456,716 ha (1,128,566 ac) of potential mountain yellow-legged frog habitat.

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## BIOLOGICAL INFORMATION

### *Species Description*

The body length (snout to vent) of the mountain yellow-legged frog ranges from 40 to 80 millimeters (mm) (1.5 to 3.25 inches (in)) (Jennings and Hayes 1994, p. 74). Females average slightly larger than males and males have a swollen, darkened thumb base (Wright and Wright 1949, pp. 424–430; Stebbins 1951, pp. 330–335; Zweifel 1955, p. 235, 1968, p. 65.1). Dorsal (upper) coloration in adults may be variable, exhibiting a mix of brown and yellow, but it also can be grey, red, or green-brown, and usually patterned with dark spots (Stebbins 2003, p. 233; Jennings and Hayes 1994, p.74). These spots may be large (6 mm (0.25 in)) and few, smaller and more numerous, or a mixture of both (Zweifel 1955, p. 230). Irregular lichen or moss-like patches (to which the name *muscosa* refers) also may be present on the dorsal surface (Zweifel 1955, pp. 230, 235; Stebbins 2003, p. 233). The belly and undersurfaces of the hind limbs are yellow or orange, and this pigmentation on the abdomen may extend forward to the forelimbs (Wright and Wright 1949, pp. 424–429; Stebbins 2003, p.233). This species may produce a distinctive mink or garlic-like odor when disturbed (Wright and Wright 1949, p. 432; Stebbins 2003, p. 233). Although the species lacks vocal sacs, it can make both terrestrial and underwater vocalizations, which have been described as a flat clicking sound (Zweifel 1955, p. 234; Stebbins 2003, p. 233; Ziesmer 1997, pp. 46–47). The mountain yellow-legged frog has smoother skin, generally heavier spotting and mottling dorsally, and darker toe tips than the foothill yellow-legged frog (*R. boylei*) (Zweifel 1955, p. 234) with undersurface coloration generally more opaque than *R. boylei* (Stebbins 2003, pp. 233).

Eggs of the mountain yellow-legged frog are laid in globular clumps, which are often somewhat flattened, roughly 2.5 to 5 cm (1 to 2 in) across (Stebbins 2003, p. 444). When eggs are close to hatching, egg mass volume may average 198 cubic cm (78 cubic in) (Pope 1999a, p. 30). Eggs have three firm jelly-like transparent envelopes surrounding a grey-tan or black vitelline (egg yolk) capsule (Wright and Wright 1949, pp. 431–433).

The larvae (tadpoles) of this species generally are mottled brown in dorsal coloration with a golden tint and a faintly-yellow venter (underside) (Zweifel 1955, p. 231; Stebbins 2003, p. 460). Total tadpole length reaches 72 mm (2.8 in), its body is flattened, and the tail musculature

is wide, about 2.5 centimeters (cm) (1 in) or more, before tapering into a rounded tip (Wright and Wright 1949, p. 431). The mouth has a maximum of 8 labial (lip) tooth rows (2-4 upper and 4 lower) (Stebbins 2003, p. 460). Larvae may take more than 1 year (Wright and Wright 1949, p. 431) and often take 2 to 4 years to reach metamorphosis (transformation from larvae to frogs) (Cory 1962b, p. 515; Bradford 1983, pp. 1171, 1182 ; Bradford *et al.* 1993, p. 883; Knapp and Matthews 2000, p. 435).



Photo Credit - USFWS

### *Taxonomy*

Camp (1917, pp. 118–123) described the mountain yellow-legged frog as two subspecies of *Rana boylei*: *R. b. sierrae* in the Sierra Nevada, and *R. b. muscosa* in southern California. On the basis of the similar morphological (body structure) characteristics of the two subspecies, the small number of sites where both were found, and breeding experiments, *R. b. muscosa* and *R. b. sierrae* were split from the *R. boylei* group and combined under a single species, *R. muscosa* (Zweifel 1955, pp. 272–273). Genetic studies also have suggested that *R. muscosa* and *R. boylei* are distinct species (Case 1978, p. 319; Davis 1986; Green 1986a, p. 273, 1986b, p. 283; Hillis

and Davis 1986, p. 1282; Macey *et al.* 2001, p. 131; Hillis and Wilcox 2005, pp. 306–307). Based on mitochondrial DNA, morphological, and acoustic studies, Vredenburg *et al.* (2007, p. 371) recently recognized two distinct species of mountain yellow-legged frog in the Sierra Nevada, *R. muscosa* and *R. sierrae*. This taxonomic distinction has been recently adopted by the American Society of Ichthyologists and Herpetologists, the Herpetologists' League, and the Society for the Study of Amphibians and Reptiles (Crother *et al.* 2008, p. 11). The Vredenburg study determined that two species exist, as described by Camp (1917, pp. 118–123), but have different geographical ranges than first described. Camp described *R. muscosa* as only occurring in southern California. A recent study determined that *R. muscosa* also occurs in the southern portion of the Sierra Nevada and *R. sierrae* occurs both in the southern and northern portions of the Sierra Nevada with no range overlap (Vredenburg *et al.* 2007, p. 361). While this information may affect the management approach for the conservation of the mountain yellow-legged frog, verification of, and additional information on, these findings must be obtained prior to addressing the mountain yellow-legged frog as two distinct species. At this time, we have not adopted this taxonomic distinction of two species and continue to recognize mountain yellow-legged frogs in the Sierra Nevada Mountains of California as *R. muscosa* and as the candidate entity.

### *Habitat/Life History*

Mountain yellow-legged frogs rarely are found more than 1 m (3.3 ft) from water (Stebbins 1951, p. 340; Mullally and Cunningham 1956, p. 191; Bradford *et al.* 1993, p. 886). At the lower elevations in the Sierra Nevada, the species usually is associated with rocky stream beds and wet meadows surrounded by coniferous forest (Zweifel 1955, p. 237; Zeiner *et al.* 1988, p. 88). At higher elevations, the species occupies lakes, ponds, tarns, and streams (Zweifel 1955, p. 237; Mullally and Cunningham 1956, p. 191). The borders of alpine (above the tree line) lakes and montane (mountain) meadow streams used by mountain yellow-legged frogs are frequently grassy or muddy; this differs from the sandy or rocky shores that are inhabited by the amphibian in lower elevation streams (Zweifel 1955, pp. 237–238). Adults typically are found sitting on rocks along the shoreline, usually where there is little or no vegetation (Mullally and Cunningham 1956, p. 191). Although the species may use a variety of shoreline habitats, both larvae and adults are less common at shorelines which drop abruptly to a depth of 60 cm (2 ft) than at open shorelines that gently slope up to shallow waters of only 5–8 cm (2–3 in) deep (Mullally and Cunningham 1956, p. 191; Jennings and Hayes 1994, p. 77). Mountain yellow-legged frogs also use stream habitats, especially in the northern part of their range. Streams utilized by adults vary from those having high gradients with numerous pools, rapids, and small waterfalls, to those with low gradients with slow flows, marshy edges, and sod banks (Zweifel 1955, p. 237). Aquatic substrates vary from bedrock to fine sand, rubble (rock fragments), and boulders (Zweifel 1955, p. 237). Mountain yellow-legged frogs seem to be absent from the smallest creeks, probably because these have insufficient depth for adequate refuge and overwintering habitat (Jennings and Hayes 1994, p. 77).

Both adults and larvae overwinter for up to nine months in the bottoms of lakes that are at least 1.7 m (5.6 ft) deep; however, overwinter survival may be greater in lakes that are at least 2.5 m (8.2 ft) deep, under ledges of stream or lake banks, or in rocky streams (Bradford 1983, p. 1179; Vredenburg *et al.* 2005, p. 565). In some instances, frogs have been found to overwinter in underwater bedrock crevices between 0.2 m (0.7 ft) and 1 m (3.3 ft) below the water surface (Matthews and Pope 1999, p. 619) and the use of such crevices appears to allow them to survive in shallower water bodies that freeze to the bottom in winter (Pope 1999a, pp. 43–44). In lakes and ponds that do not freeze to the bottom in winter, mountain yellow-legged frogs may overwinter in the shelter of bedrock crevices as a behavioral response to the presence of introduced fishes (Vredenburg *et al.* 2005, p. 565).

Adult mountain yellow-legged frogs breed in the shallows of ponds or in inlet streams and are often seen on wet substrates within 1 m (3 ft) of the water's edge (Vredenburg *et al.* 2005, p. 565). Adults emerge from overwintering sites immediately following snowmelt and will move over ice to get to breeding sites (Pope 1999a, pp. 46–47; Vredenburg *et al.* 2005, p. 565). Mountain yellow-legged frogs in the Sierra Nevada deposit their eggs underwater in clusters which they attach to rocks, gravel, vegetation, or under banks (Wright and Wright 1949, p. 431; Stebbins 1951, p. 341; Zweifel 1955, p. 243; Pope 1999a, p. 30). Clutch size varies from 15 to 350 eggs per egg mass (Livezey and Wright 1945, p. 703; Vredenburg *et al.* 2005, p. 565). In laboratory breeding experiments, egg hatching times ranged from 18 to 21 days at temperatures ranging from 5 to 13.5 Celsius (°C) (41 to 56 Fahrenheit (°F)) (Zweifel 1955, pp. 262–264). Field observations show similar results. (Pope 1999a, p. 31).

The time required to develop from fertilization to metamorphosis is believed to vary between 1 and 4 years (Wright and Wright 1949, p. 431; Zweifel 1955, pp. 244–245; Cory 1962b, p. 515; Vredenburg 2004, p. 7646). Since larvae must overwinter at least two or three times before metamorphosis, successful breeding sites are located in, or connected to, lakes and ponds that do not dry in the summer, and that are sufficiently deep so as to not completely freeze through in winter. Larval survival to metamorphosis is possible in lakes that do not dry out during the summer. Knapp and Matthews (2000, p. 435) found the number of larvae was larger in fishless water bodies deeper than 2 m (6.5 ft). Bradford (1983, p. 1173) found that mountain yellow-legged frog die-offs sometimes result from oxygen depletion during winter in lakes less than 4 m (13 ft) deep. However, larvae may survive for months in nearly anoxic (oxygen-deficient) conditions when shallow lakes are frozen to the bottom. Recent studies have reported populations of mountain yellow-legged frogs overwintering in lakes less than 1.5 m (5 ft) deep that were assumed to have frozen to the bottom, and yet healthy frogs were documented to emerge the following July (Matthews and Pope 1999, pp. 622–623; Pope 1999a, pp. 42–43). Radio telemetry indicated that the mountain yellow-legged frogs were utilizing rock crevices near shore, crevices, holes, and ledges where water depths ranged from 0.2 m (0.7 ft) to 1.5 m (5 ft) (Matthews and Pope 1999, p. 619). The granite surrounding these overwintering habitats may insulate the mountain yellow-legged frogs from the extreme winter temperatures, providing that there is an adequate supply of oxygen either in the water or air (Matthews and Pope 1999, p. 622).

Larvae maintain a relatively high body temperature by selecting warmer microhabitats (Bradford 1984, p. 973). During winter, larvae remain in warmer water below the thermocline (thermally stratified water); after spring overturn (thaw and thermal mixing of the water), they continue to behaviorally modulate their body temperature by daily movements: during the day, larvae move to warm, shallow, near-shore water, and during the late afternoon and evening, they retreat to the warmer waters off shore (Bradford 1984, p. 974).

The time required to reach reproductive maturity is thought to vary between 3 and 4 years after metamorphosis (Zweifel 1955, p. 254). Longevity of adults is unknown, but adult survivorship from year to year is very high, so they are undoubtedly long-lived amphibians (Pope 1999a, p. 46). Although data currently are limited, evidence exists that mountain yellow-legged frogs display strong site fidelity and return to the same overwintering and summer habitats from year to year (Pope 1999a, p. 45).

In aquatic habitats, mountain yellow-legged frog adults typically move only a few hundred meters (few hundred yards) (Matthews and Pope 1999, p. 623; Pope 1999a, p. 45), but distances of up to 1 km (0.62 mi) have been recorded (Vredenburg 2002, p. 4). Adults tend to move between selected breeding, feeding, and overwintering habitats during the course of the year. Though adults are typically found within 1 m (3.3 ft) of water, overland movements of over 65 m (215 ft) have been recorded (Pope 1999a, p. 45); the furthest reported distance of a mountain yellow-legged frog from water is 400 m (1,300 ft) (Vredenburg 2002, p. 4). Almost no data exist on the dispersal of juvenile mountain yellow-legged frogs away from breeding sites; however, juveniles that may be dispersing to permanent water have been observed in small intermittent streams (Bradford 1991, p. 176). Regionally, mountain yellow-legged frogs are thought to exhibit a metapopulation structure (Bradford *et al.* 1993, p. 886; Drost and Fellers 1996, p. 424). In describing the metapopulation concept, Hanski and Simberloff (1997, p. 6) stated: "...the two key premises in this approach to population biology are that populations are spatially structured in assemblages of local breeding populations and that migration among the local populations has some effect on local dynamics, including the possibility of population reestablishment following extinction."

Adult mountain yellow-legged frogs are thought to feed preferentially upon terrestrial insects and adult stages of aquatic insects while on the shore and in shallow water (Bradford 1983, p. 1171). Feeding studies on Sierra Nevada mountain yellow-legged frogs are limited. Remains found inside the stomachs of mountain yellow-legged frogs in southern California include a wide variety of invertebrates, including beetles, ants, bees, wasps, flies, true-bugs, and dragonflies (Long 1970, p. 7). Larger frogs take more aquatic true bugs (insects in the taxonomic order Hemiptera) probably because of their more aquatic behavior (Jennings and Hayes 1994, p. 77). Adult mountain yellow-legged frogs have been found to eat Yosemite toad (*Bufo canorus*) larvae (Mullally 1953, p. 183; Zeiner *et al.* 1988, p. 88) and Pacific treefrog (*Pseudacris regilla*) larvae (Pope 1999b, p. 163–164) and can be cannibalistic (Heller 1960, p. 127; Vredenburg *et al.* 2005, p. 565). Mountain yellow-legged frog larvae graze on benthic detritus, algae, and diatoms along rocky bottoms in streams, lakes, and ponds (Bradford 1983, p. 1171; Zeiner *et al.* 1988, p. 88). Larvae have also been observed cannibalizing conspecific (of the same species) eggs



(Vredenburg 2000, p. 170). In addition, larvae have been seen feeding on the carcasses of dead metamorphosed frogs (Vredenburg *et al.* 2005, p. 565).

#### *Historical Range/Distribution*

Since the mountain yellow-legged frog observations of Grinnell and Storer (1924, pp. 664–665), a number of researchers have reported disappearances of this species from significant portions of its historic range in the Sierra Nevada (Hayes and Jennings 1986, p. 490; Bradford 1989, p. 775; Jennings and Hayes 1994, p. 78; Bradford *et al.* 1994a, pp. 323–327; Jennings 1995, p. 133, 1996, pp. 934–935; Stebbins and Cohen 1995, pp. 225–226; Drost and Fellers 1996, p. 414; Knapp and Matthews 2000, p. 428; Vredenburg *et al.* 2005, p. 564). The magnitude of observed declines of mountain yellow-legged frog populations in the 1970s was small relative to the declines observed during the 1980s and 1990s. As of 2000 it was estimated that mountain yellow-legged frog populations had undergone a 50 to >80 percent reduction in size (Bradford *et al.* 1994a, pp. 324–325; Jennings 1995, p. 133; Drost and Fellers 1996, p. 419; Jennings 1996, pp. 934–935; Knapp and Matthews 2000, p. 429). However, the most recent analysis of their status indicates that Sierra Nevada mountain-yellow legged frogs no longer occur at >90 percent of the sites where historic collections of this species were made (Knapp 2005b; Vredenburg *et al.* 2007, p. 362). The most pronounced declines have occurred north of Lake Tahoe in the northernmost 125 km (78 mi) portion of the range, and south of Sequoia and Kings Canyon National Parks in Tulare County in the southernmost 50 km (31 mi) portion, where only a few populations remain (Fellers 1994, p. 5; Jennings and Hayes 1994, pp. 74–78). Based on available USFS survey and observation data, there appear to be no large populations north of the Plumas National Forest.

Mountain yellow-legged frogs historically occurred in Nevada on the slopes of Mount Rose in Washoe County and probably in the vicinity of Lake Tahoe in Douglas County (Linsdale 1940, pp. 208–210; Zweifel 1955, p. 231; Jennings 1984, p. 52). In 1994 and 1995, mountain yellow-legged frog surveys were conducted by Panik (1995, p. 2) at 54 sites in the Carson Range of Nevada and California, including eight historic locations; no mountain yellow-legged frogs were observed. A few scattered and unconfirmed sightings were reported in Nevada in the late 1990s, but any populations remaining beyond the California border are likely to be extremely small and the species is thought to be extirpated from Nevada (Panik 2002, p. 1).

The number of extant populations of the mountain yellow-legged frogs in the Sierra Nevada has declined greatly. Remaining populations are patchily scattered throughout nearly all their historic range (Jennings and Hayes 1994, pp. 74–78; Jennings 1995, p. 133, 1996, p. 936). At the northernmost portions of the range, in Butte and Plumas counties, only a few populations have documented since 1970 (Jennings and Hayes 1994, pp. 74–78). Declines have also been noted in the central and southern Sierra (Drost and Fellers 1996, p. 420). In the southern Sierra Nevada (Sierra, Sequoia, and Inyo National Forests; and Sequoia, Kings Canyon, and Yosemite National Parks), relatively large populations (e.g., breeding populations of over 20 adults) of mountain yellow-legged frogs remain; however, in recent years, some of the largest of these populations have been extirpated (Bradford 1991, p. 176; Bradford *et al.* 1994a, pp. 325–326; Knapp 2002a, p. 10). Mountain yellow-legged frog populations are generally more numerous



and larger in size in the national parks of the Sierra Nevada than in the surrounding USFS lands (Bradford *et al.* 1994a, p. 323; Knapp and Matthews 2000, p. 430), however, recent rapid declines and disappearances of populations in Yosemite and Sequioia and Kings Canyon national parks have resulted from the pathogenic chytrid fungus (Rachowicz, 2005, pers. com.; Knapp 2005b, pers. com.)(see also Section C, Disease).

Between 1988 and 1991, Bradford *et al.* (1994a, pp. 323-327) resurveyed sites known historically (between 1955 and 1979) to have contained mountain yellow-legged frogs. They resurveyed 27 historic sites on the Kaweah River, a western watershed within Sequoia National Park, and did not detect mountain yellow-legged frogs at any of these locations. They resurveyed 21 historic sites within the Kern, Kings, and San Joaquin River watersheds in Sequoia and Kings Canyon National Parks, and detected mountain yellow-legged frogs at 11 of these sites. Frogs were detected at three locations out of 24 historic sites outside of Sequoia and Kings Canyon National Parks. Rangewide, their resurvey effort detected mountain yellow-legged frogs at 14 of 72 historic sites, representing an 80 percent population decline. On the basis of these results, (Bradford *et al.* 1994a, pp 324–325) estimated a 50 percent population decline in Sequoia and Kings Canyon National Parks, with more pronounced declines elsewhere in the mountain yellow-legged frog's range.

Drost and Fellers (1996, p. 415) surveyed for mountain yellow-legged frogs at sites documented by Grinnell and Storer in the early part of the 20th Century. The frog was reported to be the most common amphibian where they surveyed in the Yosemite area (Grinnell and Storer 1924, p. 664). Drost and Fellers (1996, p. 417) repeated Grinnell and Storer's 1924 survey and reported mountain yellow-legged frog presence at only 2 of the 14 sites where this animal had been previously detected. These two positive sightings consisted of a single larva at one site and a single adult female at another site. Drost and Fellers (1996, p. 417) identified and surveyed 17 additional sites with suitable mountain yellow-legged frog habitat, and these surveys resulted in the detection of three additional populations. For the 86 historically occupied mountain yellow-legged frog sites documented between 1915 and 1959 and resurveyed by Bradford *et al.* (1994a, pp. 323–327) and Drost and Fellers (1996, pp. 415–417), an 80 percent decline occurred in the number of historical frog populations. Of the 86 historic sites, only 16 were occupied at the time of resurvey.

### *Current Range/Distribution*

The distribution of the Sierra Nevada mountain yellow-legged frog is restricted primarily to publicly managed lands at high elevations, including streams, lakes, ponds, and meadow wetlands located on national forests, including wilderness and non-wilderness on the forests, and national parks. In several areas where detailed studies of the effects of chytrid fungus on the mountain yellow-legged frog are on-going, substantial declines have been observed over the past several years. For example, surveys conducted between 2005 and 2007 in Yosemite National Park mountain yellow-legged frogs were not detectable at 37 percent of 285 sites where they had been observed in 2000-2002; in 2007 in Sequoia and Kings Canyon National Parks mountain

yellow-legged frogs were not detected at 54 percent of sites where they had been recorded 3-8 years earlier (Knapp 2008, p.1).

The most recent comprehensive data compilation, completed in 2002, reported that approximately 210 known mountain yellow-legged frog populations (or populations within metapopulations) exist on the national forests within the Sierra Nevada, though not all of these populations may be reproducing successfully. In the national parks of the Sierra Nevada, the 2002 data compilation indicated that there are 758 known sites with mountain yellow-legged frogs, most of which occur within 59 different basins that have multiple breeding populations that are connected hydrologically, so that populations in each basin function as metapopulations). Within these 758 sites, 330 populations exist for which we have evidence of successful reproduction. The methods for measuring the numbers of populations and metapopulations in the national forests and the national parks have not been standardized and, therefore we must use caution when we compare national forests numbers with national park numbers. National forests with extant populations of mountain yellow-legged frogs include the Plumas National Forest, Tahoe National Forest, Humboldt-Toiyabe National Forest, Lake Tahoe Basin Management Unit (managed by the U.S. Forest Service (USFS)), Eldorado National Forest, Stanislaus National Forest, Sierra National Forest, Sequoia National Forest, and Inyo National Forest. National parks with extant populations of mountain yellow-legged frogs include Yosemite National Park, Kings Canyon National Park, and Sequoia National Park.

Knapp and Matthews (2000, p. 430) surveyed more than 1,700 high elevation (averaging 3,400 m (11,150 ft)) lakes and ponds in the Sierra National Forest's John Muir Wilderness Area and in Kings Canyon National Park, encompassing a total of approximately 100,000 hectares (ha) (247,000 acres (ac)). They found a strong negative correlation between introduced trout and the distribution of mountain yellow-legged frogs. In the summer of 2002, Knapp (2002a, p. 10) resurveyed 302 water bodies determined by 1995 to 1997 surveys to be occupied by mountain yellow-legged frogs, and resurveyed 744 of over 1,400 sites where frogs were not previously detected. Knapp found no change in status at 59 percent of these sites, but found that 41 percent of the sites had gone extinct, while 8 percent of previously unoccupied sites were colonized. These data indicate an extinction rate that is 5 to 6 times higher than the colonization rate within this study area. This high rate of extinction over a 5- to-7- year time frame suggests the species may become extinct within a few decades (assuming that the rate of extinction and recolonization observed over this time period accurately reflects the long-term rates). The documented extinctions appeared to occur non-randomly across the landscape, are spatially clumped typically, and involve the disappearance of all or nearly all mountain yellow-legged frog populations in a watershed (Knapp 2002a, p. 9). The colonization sites also appeared to be non-randomly distributed, occurring primarily in watersheds with large mountain yellow-legged frog populations (Knapp 2002a, p. 9).

An amphibian monitoring project encompassing sites across the entire range of the Sierra Nevada mountain yellow-legged frog began in 2002. Preliminary data from surveys of 94 basins indicate that mountain yellow-legged frogs were detectable in 20-25 percent of 'high probability basins' (basins with recorded observations of this species since 1990). Of 17 basins that were sampled on multiple occasions in 2002, 2003, and 2004 breeding populations of mountain

yellow-legged frogs were detected on all visits in 3 basins, on some visits in 2 basins, and no breeding was observed 12 basins (Brown 2005, pers. com.).

Davidson *et al.* (2002, p. 1591) reviewed the current status of 255 previously documented mountain yellow-legged frog locations (based on Jennings and Hayes (1994, pp. 74–78)) throughout its historic range and concluded that 83 percent of these sites are no longer occupied by this species. Vredenburg *et al.* (2007, p. 372), using data collected between 1995 and 2004 by his field crews and by USGS and California Department of Fish and Game (CDFG) biologists, determined that mountain yellow-legged frogs were undetectable at less than 93 percent of sites where historic collections had been made. The best available data from each national forest and national park is discussed individually below.

**Lassen National Forest:** Historically, mountain yellow-legged frogs occurred on the Lassen National Forest within multiple watersheds, including Butte Creek, the West Branch Feather River, and the Middle Fork Feather River (McFarland 2002, pp. 4–6). The last confirmed mountain yellow-legged frog sighting on the Lassen National Forest was made in 1966 in the area of Snag Lake in the West Branch Feather River watershed. Since 1993, the Lassen National Forest has conducted or funded informal and formal systematic amphibian surveys to assess the relative distribution and abundance of amphibian species, including the mountain yellow-legged frog. On the Lassen National Forest, mountain yellow-legged frogs have not been detected or confirmed during any of these surveys (McFarland 2002, p. 1).

**Plumas National Forest:** Based on resurvey efforts, Jennings and Hayes (1994, pp. 74–78) noted that the mountain yellow-legged frog was extirpated at a number of locations in the Plumas National Forest. As survey efforts continue by the Plumas National Forest, more mountain yellow-legged frog populations are being documented. However, most of the estimated 55 populations are small, consisting of only a few individuals (Hopkins 2002, pers. com.). The species appears to have disappeared from a significant number of historic locations, and the abundance of the species at known sites appears to be quite low.

**Tahoe National Forest:** Mountain yellow-legged frogs were present historically throughout the Tahoe National Forest and the surrounding areas of Sierra, Nevada, and Placer counties. Jennings and Hayes (1994, pp. 74–78) conclude that, based on their 1992 re-surveys of historic locations the species had been extirpated in a number of locations by 1992.

The Tahoe National Forest continues to conduct occasional amphibian surveys and records incidental observations of mountain yellow-legged frogs (Mark 2005, pers. com.). Data compiled by the Tahoe National Forest indicate that mountain yellow-legged frogs have been detected at 8 sites separated by at least 0.6 miles (1 km) since 2000. In 2000 observers noted more than 200 mountain yellow-legged frogs at two of these sites, neither of which has been noted as supporting mountain yellow-legged frogs since. In surveys conducted in 2002–2004 an average of 8 mountain yellow-legged frogs were recorded at occupied sites. The largest number of frogs observed at any site was 32 (Mark 2005, pers. com.).

Lake Tahoe Basin Management Unit: Historic sightings of the mountain yellow-legged frog in the Lake Tahoe Basin Management Unit are numerous, indicating that the species was abundant in the Lake Tahoe area (Reiner 2002, pers. com.). Today, only one known population of mountain yellow-legged frogs remains on this national forest, although in 1997, the USFS saw evidence of limited breeding near Desolation Wilderness (Reiner 2002, pers. com.). This is despite surveys for mountain yellow-legged frogs at >100 sites with suitable habitat (Muskopf 2005, pers. com.). The habitat at this site is a meadow and stream complex that is large (approximately 24 ha (60 ac)) and in good condition (Reiner 2002, pers. com.). Annual surveys of this site indicate that the population is small with no obvious trend of increase or decrease over time (Muskopf 2005, pers. com.).

Humboldt-Toiyabe National Forest: Only the westernmost portion of the Humboldt-Toiyabe National Forest is within the historic range of the mountain yellow-legged frog. A distributional map of mountain yellow-legged frogs produced by Jennings and Hayes (1994, p. 75) indicates historic collections of this species within the Humboldt-Toiyabe National Forest in California. Resurveys of locations where mountain yellow-legged frogs occurred indicate that the species had become extirpated by 1992 at a number of locations in Humboldt-Toiyabe National Forest (Jennings and Hayes 1994, p. 75). Surveys in California are ongoing. Approximately four populations (all in California) exist on this national forest (Milliron 2002a, p. 2; Murphy 2002b, pers. com.). Chytrid fungus (see Factor C, Disease, below) has been documented at one of these populations (Milliron 2002a, p. 2).

Eldorado National Forest: The mountain yellow-legged frog is distributed across the Eldorado National Forest with populations or metapopulations (multiple breeding populations within the same basin that have hydrologic connectivity between them) in the headwaters and headwater tributaries of several watersheds, including the Rubicon River, the South Fork American River, the North Fork Cosumnes River, and the North Fork Mokelumne River (Williams 2002, p. 2).

Numerous surveys for mountain yellow-legged frogs have been conducted on this national forest by the USFS, the CDFG, and several contractors between 1990 and 2002. Reproducing populations have been found at a variety of locations in high elevation areas of this national forest. Surveys for amphibians within the Eldorado National Forest in 1992 resulted in no detections of mountain yellow-legged frogs, though this may be a function of the limited area and habitat type that was surveyed (Martin 1992, p. 11). Jennings and Hayes (1994, p. 75) indicate both extirpated populations and extant populations on the Eldorado National Forest. Intensive surveys by CDFG and USFS in 2001 and 2002 resulted observations of extant populations or metapopulations of mountain yellow-legged frogs in 18 watersheds within the Eldorado National Forest. Although both the mean number of populations and population size are generally low relative to historic reports, resurveys over the past several years indicate that numbers are stable to increasing. Currently, approximately five populations exist with between 25 and 50 mountain yellow-legged frogs; these are the largest populations on the Eldorado National Forest (Williams 2005, pers. com.).

Stanislaus National Forest: A 1992 survey (Martin 1992, pp. 55–59) in the Stanislaus National Forest located mountain yellow-legged frogs at only 2 of 16 locations surveyed, and at these locations, the numbers of adults detected were small (under five). Jennings and Hayes (1994, p. 75) indicate that the species has been extirpated from a number of historic locations. There are approximately 80 extant populations of mountain yellow-legged frogs on the Stanislaus National Forest; of these, only about 8 appear to have more than 10 adults, and only 2 populations are known to have 25 to 30 adults (Conway 2002, pers. com.). At least two populations have been observed to exhibit symptoms of infection by the chytrid fungus (Holdeman 2005, pers. com.).

Yosemite National Park: Surveys over the past two decades have documented substantial and continued declines of the mountain yellow-legged frog from Yosemite National Park. From 1914 to 1920, Grinnell and Storer conducted a biological survey along a transect across the Sierra Nevada. Although systematic counts were not conducted, their documentation of mountain yellow-legged frogs at 14 sites throughout Yosemite National Park, and notes on the species' abundance provide historical records against which to compare more recent observations. For example: numerous frogs were found in lakes and streams at high elevations (Grinnell and Storer 1924); “hundreds of frogs” were found at Young Lake and frogs were “very numerous” at Westfall Meadow (Camp 1915, as cited in Drost and Fellers 1994, p. 19); and large numbers of specimens were collected; for example, 25 were taken at Vogelsang Lake (Grinnell 1915, as cited in Drost and Fellers 1994, p. 19). At Johnson Lake, Mullally and Cunningham (1956, p. 190) reported a mountain yellow-legged frog population decline between 1950 and 1955, though they did not quantify the decline. They attributed this decline to the unusually long and cold winter of 1951–1952. Some of Yosemite's “densest aggregations of frogs ever noted” were in lakes near Ostrander Lake south of Glacier Point; the authors attributed the absence of frogs in Ostrander Lake to the presence of nonnative trout (Mullally and Cunningham 1956, p. 190).

Between 1988 and 1991, Bradford *et al.* (1994a, pp. 324–327) resurveyed four randomly selected sites noted as supporting mountain yellow-legged frogs at some point between 1955 and 1979. No mountain yellow-legged frogs were detected at any of these four historically occupied sites (Bradford *et al.* 1994a, p. 324). In 1992 and 1993, Drost and Fellers (1996, pp. 415–417) revisited 38 of the original 40 sites surveyed by Grinnell and Storer from 1914 to 1920, and surveyed other sites with potential mountain yellow-legged frog habitat. The mountain yellow-legged frog had declined by approximately 80 percent from the locations documented by the 1924 study (Drost and Fellers 1996, p. 417). A distribution map of mountain yellow-legged frogs produced by Jennings and Hayes (1994, p. 75) also documents extinctions and indicates a population decline of this species from Yosemite National Park. Colwell and Beatty (2002, pp. 4, 12) surveyed 35 lakes with appropriate mountain yellow-legged frog habitat within the Tuolumne and Merced River drainages of Yosemite National Park in 1992 and 1993; only 3 lakes were found to have mountain yellow-legged frogs.

Knapp (2005a, p. 265) surveyed 2655 lentic water bodies in Yosemite National Park between 2000 and 2002, detecting mountain yellow-legged frogs in 285 water bodies. Between 2005 and 2007, he resurveyed all sites where mountain yellow-legged frogs were detected in his

2000-2002 surveys. He detected no mountain yellow-legged frogs at 107 (37 percent) of these sites (Knapp 2008, p. 1). Assays of mountain-yellow legged frogs captured at 43 water bodies in 2005 indicate that 91 percent of the remaining populations were infected by chytrid fungus (Knapp 2005b). Field and laboratory experiments indicate that chytrid infection is generally lethal to mountain yellow-legged frogs and is likely responsible for recent declines (Knapp 2005b; Rachowicz 2005, pers. com.) (see Factor C, Disease, below).

**Inyo National Forest:** Jennings and Hayes (1994, pp. 74–78) document the extirpation of some mountain yellow-legged frog populations from the Inyo National Forest. In 1994, 15 known locations had mountain yellow-legged frog populations (Parker 1994, p. 8). Currently, 7 basins within the Inyo National Forest have known extant mountain yellow-legged frog populations or populations that function as metapopulations (Milliron 2002a, p. 2). Some of these populations are stable, consisting of several hundred individuals representing all age classes (Sims 2002, p. 2). Chytrid fungus (see Factor C, Disease, below) has been documented at an additional population location that is now extinct (Milliron 2002a, p. 2).

**Sierra National Forest:** In 1955, Mullally and Cunningham (1956, p. 190) reported encountering mountain yellow-legged frogs along Paiute Creek “very sparingly” at approximately 2,300 m (7,700 ft), with frogs becoming more abundant at higher elevations. The “densest populations” were found above 3,050 m (10,000 ft) in the Humphrey’s Basin area, and a “great many, including tadpoles” were noted at and near Pine Creek Pass, with frogs also seen at Golden Trout and Desolation Lakes.

Jennings and Hayes (1994, pp. 74–78) indicated that the mountain yellow-legged frog has become extirpated at a number of historical locations in the Sierra National Forest. Knapp and Matthews (2000, p. 433) report on mountain yellow-legged frog population declines associated with fish stocking within the John Muir Wilderness Area of the Sierra National Forest. In 1995 and 1996, Knapp and Matthews (2000, p. 434) surveyed 669 lakes, ponds, and other water bodies in the John Muir Wilderness Area. Mountain yellow-legged frog adults were found in 4 percent of these water bodies, and frog larvae in 3 percent (Knapp and Mathews 2000, p. 433). In 2002, Knapp conducted resurveys at the 28 water bodies that had been occupied by mountain yellow-legged frogs in 1997, and also at 118 of the 641 sites where frogs were not detected in 1997. Knapp found that mountain yellow-legged frogs were no longer detectable at 61 percent of formerly occupied bodies of water, and that frogs were now detectable at 10 percent of the previously unoccupied sites (Knapp 2002a, p. 10). The most recent information indicates that there are 29 sites occupied by mountain yellow-legged frogs in Sierra National Forest (Strand 2005, pers. com.).

Although not all potential mountain yellow-legged frog habitats have been surveyed within the Sierra National Forest, approximately six sub-watersheds have extant metapopulations (Eddinger 2002, pers. com.). These sub-watersheds are in the upper headwaters of the South Fork Merced River, South Fork San Joaquin River, and North Fork Kings River. They include the Mono Creek Basin, the Bear Creek Basin, the Paiute Creek Basin, the Humphreys Creek Basin, the Big Creek Basin, and the Dinkey Creek Basin.

Sequoia and Kings Canyon National Parks: Relatively few records exist for mountain yellow-legged frog prior to 1955 in the Sequoia and Kings Canyon National Parks. From 1955 to 1979, the species is known to have occurred in at least 21 sites scattered throughout Sequoia and Kings Canyon National Parks (Bradford *et al.* 1994a, p. 325), but historic abundance is not known. In 1978-1979, the headwaters of seven creek systems were surveyed for mountain yellow-legged frogs in the national parks. Frogs were found at 27 sites greater than 200 m (660 ft) apart (Bradford *et al.* 1994a, p. 325). A distributional map of mountain yellow-legged frogs produced by Jennings and Hayes (1994, p. 75) indicates numerous historic sightings and collections of the species within both national parks, as well as numerous extinctions. On the basis of surveys, Bradford *et al.* (1994a, pp. 323–327) estimate that mountain yellow-legged frogs had been extirpated from half of their historic locations in Sequoia and Kings Canyon National Parks by the late 1980's. Fellers (1994, p. 5) also found evidence of decline in the parks, including the complete failure to detect any frogs in the previously occupied Kaweah watershed.

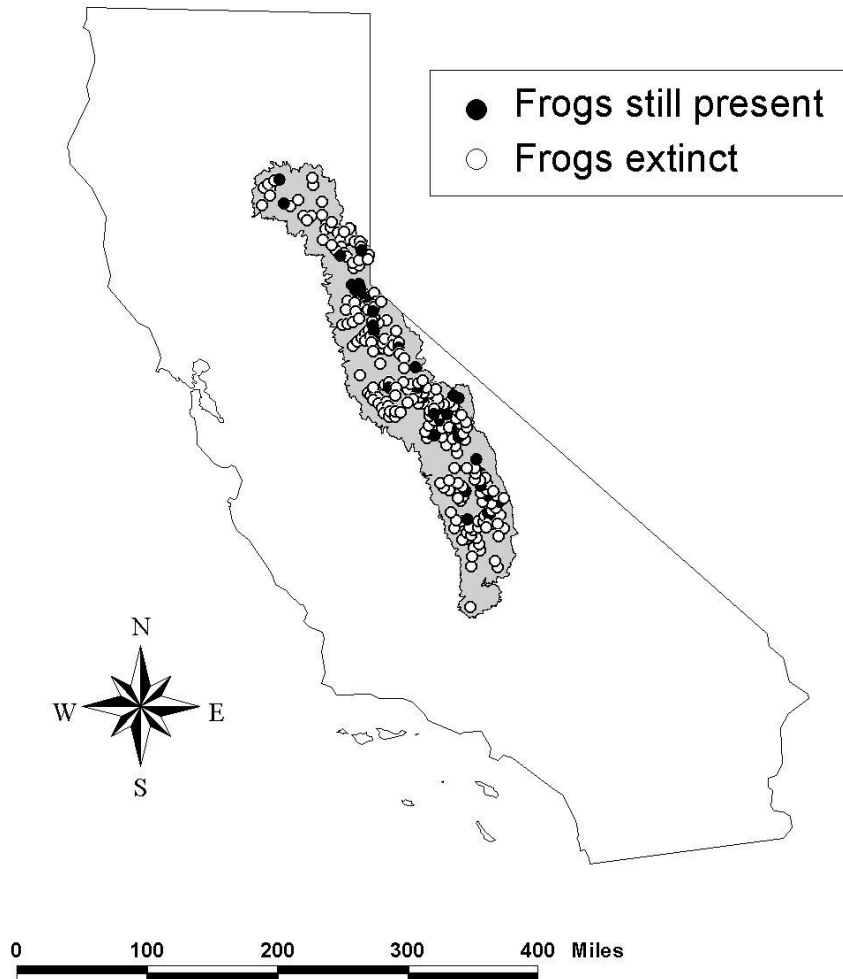
As of 2002 Sequoia and Kings Canyon National Parks supported 558 known mountain yellow-legged frog sites, most within 36 different basins each with multiple breeding populations that are hydrologically connected, so that the populations within each basin function as a metapopulation. Fifty-four sites had populations of more than 100 adult mountain yellow-legged frogs, 25 sites had populations between 51 and 100 adults, 132 sites had populations between 10 and 50 adults, 296 sites had fewer than 10 adults, and specific information has not yet been analyzed for the remaining 51 sites. Of the 558 mountain yellow-legged frog sites in Sequoia and Kings Canyon National Parks, breeding evidence was observed at 259 populations (Knapp 2002a, p. 2). Between 2005 and 2007 Knapp (2008, p. 1) resurveyed all 558 sites in the parks where mountain-yellow legged frogs were previously observed in 1997, 2000, 2001, or 2002; he detected the species at 254 sites (54 percent) of sites. Declines associated with chytrid infection have been observed in at least two lake basins in 2005 (Knapp 2005b). Six infected populations monitored declined by an average of 88 percent, 19 percent of populations assayed in 2003 and 2004 were infected with this pathogen, and 16 percent of the uninfected populations reassayed in 2004 had become infected (Rachowicz 2005, pers. com.)(See Factor C; Disease, below).

Sequoia National Forest: Jennings and Hayes (1994, pp. 74–78) indicate that the mountain yellow-legged frog has been extirpated from a number of historical locations in the Sequoia National Forest. Mountain yellow-legged frogs were collected on several historic locations of the Kern Plateau in Sequoia National Forest (Jennings and Hayes 1994, p. 75). Today, two known extant populations exist on the Sequoia National Forest (Anderson 2002, p. 1).

All of the recent mountain yellow-legged frog sightings from the Sequoia National Forest have been of single frogs or very small populations. In 1992, mountain yellow-legged frogs were not detected during amphibian surveys conducted at 17 sites in Sequoia National Forest (Martin 1992, pp. 63–68). The species appears to be severely reduced in numbers and range in the Sequoia National Forest.



## Historic and current mountain yellow-legged frog distribution



Adapted from Jennings and Hayes (1994)

### *Population Estimates/Status*

The most recent assessment of the species status in the Sierra Nevada indicates that mountain-yellow legged frogs occur at less than 8 percent of the sites from which they were historically observed (Vredenburg *et al.* 2007, p. 372). A group of prominent scientists further suggest a 10 percent decline per year in the number of remaining *R. mucosa* populations and urge the listing of the mountain yellow-legged frogs as endangered (Knapp *et al.* 2007b, p. 1–2).

## DISTINCT POPULATION SEGMENT (DPS)

Under the Act, we must consider for listing any species, subspecies, or, for vertebrates, any distinct population segment (DPS) of these taxa if there is sufficient information to indicate that such action may be warranted. To implement the measures prescribed by the Act, we, along with the National Marine Fisheries Service (National Oceanic and Atmospheric Administration–Fisheries), developed a joint policy that addresses the recognition of DPSs for potential listing actions (61 FR 4722). The policy allows for a more refined application of the Act that better reflects the biological needs of the taxon being considered, and avoids the inclusion of entities that do not require the Act’s protective measures.

Under our DPS Policy, we use two elements to assess whether a population segment under consideration for listing may be recognized as a DPS. The elements are: (1) the population segment’s discreteness from the remainder of the species to which it belongs; and (2) the significance of the population segment to the species to which it belongs. If we determine that a population segment being considered for listing is a DPS, then the level of threat to the population is evaluated based on the five listing factors established by the Act to determine if listing it as either threatened or endangered is warranted.

*Discreteness.* Under our DPS Policy, a population segment of a vertebrate species may be considered discrete if it satisfies either one of the following two conditions: (1) it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation; or (2) it is delimited by international governmental boundaries within which significant differences in control of exploitation, management of habitat, conservation, status, or regulatory mechanisms exist. The proposed DPS, the Sierra Nevada mountain yellow-legged frog, is based on the first condition, the marked separation from other populations.

The range of the mountain yellow-legged frog is divided by a natural geographic barrier, the Tehachapi Mountains, which geographically isolates the populations in the southern Sierra Nevada from those in the mountains of southern California. The distance of the geographic separation is about 225 km (140 mi). The geographic separation of the Sierra Nevada and southern California mountain yellow-legged frogs was recognized in the earliest description of the species by Camp (1917, p. 118–123), who treated specimens from the two areas as separate subspecies of *R. boylei*. Camp (1917, p. 118–123) described the two subspecies based on differences in their biogeography and morphology.

Ziesmer (1997, pp. 1–50) analyzed vocalizations of mountain yellow-legged frogs from 86 locations in Alpine and Mariposa counties in the Sierra Nevada, and vocalizations of mountain yellow-legged frogs from 23 locations in the San Jacinto Mountains of Riverside County in southern California. The vocalizations of Sierra Nevada frogs differed from those of southern California frogs in pulse rate, harmonic structure, and dominant frequency. Ziesmer (1997, p. 50) concluded that the differences in vocalization supported the hypothesis that

mountain yellow-legged frogs from the Sierra Nevada and southern California may represent separate species.

Genetic analyses support the discreteness of the mountain yellow-legged frog populations in southern California from those in the Sierra Nevada. In an allozyme (genetic) study that compared mountain yellow-legged frogs from the central Sierra Nevada with those from southern California, a fairly significant genetic difference was found between the two populations (Green 1993, p. 1). However, because there were no frog samples from the southern Sierra Nevada for comparison, it was not clear whether the difference reflected two ends of a cline (a character gradient), or distinctions between the Sierra Nevada and southern California populations. Recent genetic analysis of the mountain yellow-legged frog populations throughout their range detected a significant genetic difference between mountain yellow-legged frogs from the southern Sierra Nevada with those from southern California (Vredenburg *et al.* 2007, p. 367). (see Taxonomy for additional information).

A phylogenetic analysis of mitochondrial deoxyribonucleic acid (DNA) sequences of the mountain yellow-legged frog was performed throughout its distribution (Macey *et al.* 2001, p. 131). This study concluded that there are two major genetic lineages of the mountain yellow-legged frog (inclusive of the Sierra Nevada populations and the southern California populations), with populations in the Sierra Nevada falling into three distinct groups and the fourth being the southern California population (Macey *et al.* 2001, p. 141). Analysis of additional DNA sequences was conducted, concluding there were five distinct groups in the Sierra Nevada and a sixth being the southern California population (Vredenburg *et al.* 2007, p. 367). Although multiple genetic lineages of mountain yellow-legged frogs have been identified in the Sierra Nevada, and Vredenburg *et al.* (2007, p. 361) proposes there are two distinct species in the Sierra Nevada, more genetic sampling and verification of findings is needed to delineate specific boundaries.

The biogeographic fragmentation within the Sierra Nevada population of mountain yellow-legged frogs occurs between Kings Canyon National Park and a region slightly north of Yosemite National Park, allowing for the central and northern Sierra Nevada populations to share more genetic similarities than the southern Sierra Nevada and southern California populations (Macey *et al.* 2001, p. 140). In fact, this study indicates that the southern Sierran group (largely in Fresno County) may be more closely related to the southern California mountain yellow-legged frogs than with those in the central and northern Sierra Nevada (Macey *et al.* 2001, p. 140). This research suggests that the initial divergence between the northern and southern populations of mountain yellow-legged frogs occurred 2.2 million years before present. Within each of these groups, Macey *et al.* (2001, p. 140) have detected a similar pattern of divergence that suggests the northern Sierra Nevada and central Sierra Nevada mountain yellow-legged frog populations diverged 1.5 million years before present, and the southern Sierra Nevada and the southern California mountain yellow-legged frog populations diverged from each other approximately 1.4 million years before present. Today, these 4 groups are isolated by arid valleys; this isolation is most pronounced between southern California and the southern Sierra Nevada. The biogeographic pattern of genetic divergence as detected in the mountain yellow-

legged frogs of the Sierra Nevada has also been observed in four other reptiles and amphibians, suggesting a common event that fragmented their ranges (Macey *et al.* 2001, p. 140).

Sierran frogs and southern California mountain yellow-legged frogs also differ ecologically in the types of aquatic habitat they occupy. Mountain yellow-legged frogs in southern California are typically found in steep gradient streams, even though they may range into small meadow streams at higher elevations (Zweifel 1955, p. 237; Mullally 1959, p. 78). In contrast, Sierran frogs are most abundant in high-elevation lakes and slow-moving portions of streams (Zweifel 1955, p. 237; Mullally and Cunningham 1956, p. 191), habitat that is distinct from the canyons of southern California's arid mountain ranges, which are inhabited by the southern California DPS of the mountain yellow-legged frog.

*Significance.* Under our DPS Policy, once we have determined that a population segment is discrete, we consider its biological and ecological significance to the larger taxon to which it belongs. This consideration may include, but is not limited to: (1) evidence of the persistence of the discrete population segment in an ecological setting that is unusual or unique for the taxon; (2) evidence that loss of the population segment would result in a significant gap in the range of the taxon; (3) evidence that the population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or (4) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

We have found substantial evidence that all but one (there are no introduced populations of mountain yellow-legged frogs outside of its historic range) of these significant factors are met by the population of mountain yellow-legged frogs in the Sierra Nevada. Furthermore, it is significant because a major reduction in abundance of the species as a whole would occur if the Sierra Nevada population were extirpated. The extinction of the Sierra Nevada population of the mountain yellow-legged frog would result in the loss of a genetic entity, a reduction in the geographic range of the species, a loss of the species persistence in a setting ecologically unique relative to the ecological setting of the southern California population, and a reduction in the number of breeding populations. As discussed above, the Sierra Nevada population appears to be genetically distinct from the southern California population of mountain yellow-legged frogs. The mountain yellow-legged frogs of the Sierra Nevada comprise the main distribution of the species at the northern and central limits of the species' range. Loss of the Sierra Nevada population would be significant as it would eliminate the species from the majority of its range and would reduce the species to fewer than 10 small isolated sites in southern California (50 FR 44382). The geographic isolation of the Sierra Nevada population from the mountain yellow-legged frogs in southern California prevents genetic interchange between these populations.

*Conclusion.* We evaluated the Sierra Nevada population of the mountain yellow-legged frog to determine whether it meets the definition of a DPS, addressing discreteness and significance as required by our policy. We conclude that the Sierra Nevada population of the mountain yellow-legged frog is discrete from the southern California population, on the basis of their geographic separation, differences in vocalization, differences between their habitats, and apparent genetic

differences. We conclude that the Sierra Nevada population of the mountain yellow-legged frog is significant because the loss of the species from the Sierra Nevada would result in a significant reduction in the species' range and its population numbers, and would constitute the loss of a genetically discrete population that differs markedly from the southern California population of mountain yellow-legged frogs. Because the population segment meets both the discreteness and significance criteria of our DPS policy, the Sierra Nevada portion of the mountain yellow-legged frog's range qualifies for consideration for listing. An evaluation of the level of threat to the DPS based on the five listing factors established by the Act follows.

## THREATS

*A. The present or threatened destruction, modification, or curtailment of its habitat or range.* A number of hypotheses, including habitat loss, have been proposed for recent global amphibian declines (Bradford *et al.* 1993, p. 883; Corn 1994, p. 62; Alford and Richards 1999, p. 4). Habitat destruction, however, does not appear to be the primary factor leading to the decline of the mountain yellow-legged frog. The mountain yellow-legged frog occurs at high elevations in the Sierra Nevada, which have not had the types or extent of large-scale habitat conversion and disturbances which have occurred at lower elevations (Knapp and Matthews 2000, p. 429). Large scale habitat conversion has not been identified within the range of this species; thus, direct habitat destruction or modification associated with intensive human activities, as measured by urban or agricultural land use within the mountain yellow-legged frogs' range, has not been implicated in the decline of this species (Davidson *et al.* 2002, p. 1597). However, other human activities have played a role in the modification of mountain yellow-legged frog habitat. These include livestock grazing, nonnative fish introductions (see Predation, Factor C, below), timber management, road construction and maintenance, recreation, water diversions, fire management activities, and introduction of environmental contaminants (see Other, Factor E, below). These activities have modified habitat in ways that have fragmented and isolated mountain yellow-legged frog populations, and thereby, may have caused or contributed to the decline of this DPS (Bradford *et al.* 1993, pp. 887–888).

### *Grazing*

Grazing of livestock in Sierra Nevada meadows and riparian areas (aquatic ecosystems and adjacent upland areas that directly affect them) began in the mid-1700s with the European settlement of California (Menke *et al.* 1996, p. 7). Following the gold rush of the mid-1800s, grazing rose to a level that exceeded the carrying capacity of the available range and caused significant impacts to meadow and riparian ecosystems (Meehan and Platts 1978, p. 275; Menke *et al.* 1996, p. 7). From 1870 to 1908, within the range of the mountain yellow-legged frog in the high Sierra Nevada, meadows were converted to summer rangelands for grazing cattle, sheep, horses, goats, and in some areas pigs; however, the alpine areas were mainly grazed by sheep (Beesley 1996, p. 7–8; Menke *et al.* 1996, p. 14). This practice resulted in the degradation of these extremely sensitive areas (Menke *et al.* 1996, p. 14).

In general, livestock grazing within the range of the mountain yellow-legged frog was at a high but undocumented level until the establishment of national parks (beginning in 1890) and national forests (beginning in 1905). Within established national parks, grazing by cattle and sheep was replaced by that of packstock, such as horses and burros. Within established national forests, the amount of livestock grazing was gradually reduced and better documented, and the types of animals shifted, with reductions in sheep and increases in cattle and packstock. In general, livestock grazing within the national forests has continued with gradual reductions since the 1920s, except for an increase during World War II. Continuing decreases, motivated by concern towards resource protection, conflicts with other uses, and deteriorating range conditions, continued from the 1950s through the early 1970s but still exceeded sustainable grazing capacity in many areas (Menke *et al.* 1996, p. 9; University of California (UC) 1996a, p. 115), and the management approach has been described as being "...without adequate safeguards for riparian habitats" (UC 1996a, p. 115). Grazing management that is more sensitive to riparian areas has continued to increase since the 1970s (UC 1996a, p. 115).

Packstock grazing is the only grazing currently permitted in the Sierra Nevada national parks. Packstock grazing also is permitted in national forests within the Sierra Nevada. However, there has been very little monitoring of the impacts of packstock use in this region (Menke *et al.* 1996, p. 14). Use of packstock in the Sierra Nevada increased since World War II as a result of increased road access and increases in leisure time and disposable income (Menke *et al.* 1996, p. 14). As California's human population increases, demand for recreational activities in the Sierra Nevada are projected to increase (USDA 2001a, pp. 473–474), including packstock use and recreational riding

Observational data indicate livestock negatively impact mountain yellow-legged frog populations by altering frog habitat and trampling individuals (Knapp 1993a, p. 1, 1993b, p. 1, 1994, p. 3, 2002a, p. 29; Jennings 1996, p. 938; Carlson 2002b, pers. com.). Livestock tend to concentrate along streams and wet areas where there is water and herbaceous vegetation. Grazing impacts are most pronounced in these habitats (Meehan and Platts 1978, p. 274; Fleischner 1994, p. 635; Menke *et al.* 1996, p. 17; U.S. Government Accounting Office (GAO) 1988, pp. 10–11), contributing to the destabilization of streambanks causing undercuts and bank failures (Kauffman *et al.* 1983, p. 684; Marlow and Pogacnik 1985, pp. 282–283; Knapp and Matthews 1996, p. 816; Moyle 2002, p. 55), compacting soils, and creating trampling damage to the soils and vegetation. These impacts result in reductions in water infiltration rates and the soil's ability to hold water, thereby increasing the rapidity of surface runoff into adjacent streams, the downcutting of stream beds, and the lowering of the watertable (Meehan and Platts 1978, pp. 275–276; Kauffman *et al.* 1983, p. 685; Kauffman and Krueger 1984, p. 432; Bohn and Buckhouse 1985, p. 378; GAO 1988, p. 11; Armour *et al.* 1994, pp. 9–11; Moyle 2002, p. 55). Mass erosion from trampling and hoof slide cause stream bank collapse and an accelerated rate of soil movement from land to streams (Meehan and Platts 1978, p. 274). Accelerated rates of erosion lead to elevated instream sediment loads and depositions and changes in stream channel morphology (Meehan and Platts 1978, pp. 275–276; Kauffman and Krueger 1984, p. 432). In some cases, impacts from livestock grazing have resulted in the conversion of wet meadows into dry flats and also in diminished perennial stream flows (Armour *et al.* 1994, p. 10; Moyle 2002,

p. 55). With increased grazing intensity, these associated adverse effects to the aquatic ecosystem also increase (Meehan and Platts 1978, p. 275; Clary and Kinney 2000, p. 294).

Livestock grazing causes changes in wetland systems, including meadows, streams, and ponds; modifies mountain yellow-legged frog habitat by removing overhanging banks that provide shelter; and contributes to the siltation of breeding ponds. Pond siltation may decrease the survivorship of overwintering larvae, subadults, and adult mountain yellow-legged frogs as the overwintering habitats need to be deep enough so that the entire water column does not freeze and underwater caves and crevices are available (Bradford 1983, p. 1179; Pope 1999a, pp. 43–44).

Grazing of livestock in riparian areas impacts vegetation in multiple ways, including: soil compaction, which increases runoff and decreases water availability to plants; herbage removal, which promotes increased soil temperatures and evaporation rates at the soil surface; and direct physical damage to the vegetation (Kauffman and Krueger 1984, pp. 433–434; Cole and Landres 1996, pp. 171–172; Knapp and Matthews 1996, pp. 816–817). Streamside vegetation protects and stabilizes streambanks by binding soils to resist erosion and to trap sediment (Chaney *et al.* 1990, p. 2). A study by Kauffman *et al.* (1983, p. 683) indicated that livestock grazing may have weakened the streambank structure through trampling and removal of vegetation, thereby promoting conditions for erosion. Removal of vegetative cover within mountain yellow-legged frog habitat decreases available habitat, exposes frogs to predation (Knapp 1993b), and increases the threat of dessication (Jennings 1996, p. 539). Grazing may result in changes to vegetation composition, resulting in an increased density of forested stands and the expansion of trees into areas that were formerly treeless (Cole and Landres 1996, p. 171).

Livestock grazing can cause a nutrient loading problem due to urination and defecation in or near the water, and can elevate bacteria levels in areas where cattle are concentrated near water (Meehan and Platts 1978, p. 276; Stephenson and Street 1978, p. 156; Kauffman and Krueger 1984, p. 432). The nutrient status of streams can influence the growth of microflora and microfauna and directly and indirectly affect many other characteristics of the stream biota (Lemly 1998, p. 228). Growth of filamentous bacteria on the bodies and gills of aquatic insects has been documented in association with nutrient loading in livestock use pastures, along with significantly lower densities of insects at downstream sites. In laboratory and field studies, aquatic insects with this bacterial growth experienced extensive mortality. This indicates that elevated bacteria levels associated with livestock use can negatively influence stream insect populations (Lemley 1998, pp. 234–235). Adverse effects to aquatic insects within the range of the mountain yellow-legged frog could result in lowered prey availability, possibly increasing intraspecific competition for limited resources.

Throughout the range of the mountain yellow-legged frog in the Sierra Nevada approximately 79 currently active grazing allotments exist on USFS-administered lands. Of these grazing allotments, at least 29 have extant mountain yellow-legged frog populations within them. An estimated 13 percent of the approximately 210 known mountain yellow-legged frog



populations or metapopulations, on Sierra Nevada national forests occur within active grazing allotments.

On the Inyo National Forest, four active allotments have extant mountain yellow-legged frog populations; however, only two of these four, the Coyote Creek and Monache allotments, currently have livestock grazing that affects mountain yellow-legged frog populations (Sims 2002, p. 2). The Coyote Creek allotment contains approximately 300 adult frogs in Cow Creek, and additional frogs occur elsewhere in the allotment. In 2002, cattle were removed from the Cow Creek portion of the Coyote Creek allotment about a month early because of livestock damage of the streambank in excess of allowable standards, as described in the Inyo National Forest's Land and Resource Management Plan (LRMP). Approximately half of the stream habitat available to frogs is fenced off to grazing in this allotment. The Monache Allotment has had historic sightings of adult frogs, but none were sighted during surveys in 2002. Cattle continue to graze this allotment.

Historically, the Dexter Creek allotment had both mountain yellow-legged frogs and livestock (sheep). In 1996, the sheep were removed to protect and enhance the riparian habitat and ecosystem, as well as to protect the population of mountain yellow-legged frogs; the frog habitat is not currently grazed. This population reportedly had more than 1,000 individuals representative of all age classes in 1996, but only 15 in 1997, with CDFG noting that chytrid fungus had infected individuals at the site (Sims 2002, p. 2). Frogs were not detected within the Dexter Creek allotment after repeated surveys in 2001 and 2002. Grazing and disease have affected this population; however, the factor or factors responsible for its extirpation are unclear. Today, ongoing grazing activities on the Inyo National Forest are confined to one extant metapopulation (Sims 2002, p. 2).

There are three active grazing allotments (Poison Creek, Sardine, and Lost Cannon Canyon) within the range of the mountain yellow-legged frog on the California portion of the Humboldt-Toiyabe National Forest (Murphy 2002a, p. 1). Of these three allotments, Lost Cannon Canyon is the only one known to have had mountain yellow-legged frogs historically; however, the frog has not been found there in recent surveys (Easton 2002, p. 1; Murphy 2002b, pers. com.).

The Plumas National Forest has at least six grazing allotments (Summit, Clark's Creek, Antelope, Antelope Lake, Lone Rock, and Bear allotments) with mountain yellow-legged frog populations (Rotta 2002, p. 2). In at least one of these allotments, grazing has been documented to impact occupied mountain yellow-legged frog habitat; however, in 2002 no livestock were turned out in this allotment (Rotta 2002, p. 2).

The Tahoe National Forest currently has seven active and four inactive allotments with mountain yellow-legged frog populations. Of these, two active allotments and two inactive allotments have breeding populations of frogs, although the largest population only has 10 individuals (Carlson 2002a, p. 2).

The Lake Tahoe Basin Management Unit has a total of 4 grazing allotments, but only 2, the Cold Creek and Baldwin allotments, are active. There is only 1 extant population of mountain yellow-legged frogs on the Lake Tahoe Basin Management Unit, and it is within a non-use allotment that has not been grazed for approximately 5 years (Reiner 2002, pers. com.).

The Eldorado National Forest has 17 grazing allotments within the range of the mountain yellow-legged frog and with suitable habitat, and four of these allotments are actively grazed. Of the 17 allotments, 11 have breeding populations of the mountain yellow-legged frog or have frog sightings (Williams 2005, pers. com.).

The Stanislaus National Forest has 22 grazing allotments within the range of the mountain yellow-legged frog, and all but one is active. Three of these allotments, including Cooper and Bell Meadow/Bear Lake allotments, are occupied by extant mountain yellow-legged frog populations. The Stanislaus National Forest's largest populations are outside of the grazing allotments (Conway 2002, pers. com.).

The Sierra National Forest has approximately 18 active grazing allotments at altitudes above 1,800 m (6,000 ft). Mountain yellow-legged frogs were detected at sites within at least ten of these allotments between 2002 and 2004 (Sanders 2005, pers. com.)

The Sequoia National Forest has approximately 17 grazing allotments above 1,400 m (4,500 ft) with potential habitat for the mountain yellow-legged frog; of these, 14 allotments are actively grazed. One of the two mountain yellow-legged frog populations on the Sequoia National Forest is within an active grazing allotment (Anderson 2002, p. 1).

In the 60-Lakes Basin of Kings Canyon National Park, packstock use is regulated in wet meadows to protect mountain yellow-legged frog breeding habitat in bogs and lakeshores from trampling and associated degradation (Vredenburg 2002, p. 11; Werner 2002, p. 2). However, this policy is temporary and subject to annual review by the National Park Service (NPS).

### *Recreation*

Recreation is the fastest growing use of national forests. As such, its impacts on the mountain yellow-legged frog are likely to continue and to increase (USDA 2001b, p. 213). Recreational activities take place throughout the Sierra Nevada and have significant negative impacts on several plant and animal species and their habitats (USDA 2001a, pp. 483–493). Cole and Landres (1996, p. 170) stated that the primary impacts of recreation on plant and animal species include: (1) site alteration and organismal disturbance as a result of trampling by humans and livestock; (2) the removal and redistribution of materials by packstock grazing; (3) behavioral disturbance of native animals by human presence and their belongings, particularly food; (4) the harvesting of animals and plants; and (5) the pollution of waters by human waste and foreign materials. High elevation wilderness areas, where some of the increased recreational activity is occurring, are naturally stressed ecosystems because of intense solar exposure, extremes in temperatures, precipitation levels, wind, short growing seasons, and shallow

nutrient-poor soil, and typically are not resilient to disturbance (Schoenherr 1992, p. 167; Cole and Landres 1996, p. 170).

Recreational foot traffic in riparian areas tramples vegetation, compacts soils, and can physically damage streambanks (Kondolph *et al.* 1996, pp. 1018–1020). Human foot, horse, bicycle, or off-highway motor vehicle trails replace riparian habitat with compacted soil (Kondolph *et al.* 1996, p. 1019) and can lower the water table and cause increased erosion. Also, to further recreational opportunities and angling success, nonnative trout stocking programs in the Sierra Nevada started in the late 19th Century (Bahls 1992, p. 185; Pister 2001, p. 280). Trout stocking throughout the range of the mountain yellow-legged frog has contributed to the decline of this species (see Predation, Factor C, below). The recreational impact of anglers at high mountain lakes has been severe in the Sierra Nevada, with most regions reporting a level of use greater than that which the fragile lakeshore environments can withstand (Bahls 1992, p. 190).

Recreation may threaten all life stages of the mountain yellow-legged frog through direct disturbance resulting from trampling by humans, packstock, or vehicles, including off-highway vehicles; harassment by pets; and associated habitat degradation (Cole and Landres 1996, p. 170; USDA 2001b, pp. 213–214). Studies have not been conducted to determine whether recreational activities are contributing to the decline of the mountain yellow-legged frog, and recreation has not been implicated as a cause of major decline of the mountain yellow-legged frog.

#### *Dams and Water Diversions*

Dams and water diversions have altered aquatic habitats in the Sierra Nevada (Kondolph *et al.* 1996, p. 1014). Numerous reservoirs have been constructed within the range of the mountain yellow-legged frog. These include Huntington Lake, Florence Lake, Lake Thomas A. Edison, Saddlebag Lake, Convict Lake, Cherry Lake, and other reservoirs associated with Hetch Hetchy, Upper and Lower Blue Lakes, Lake Aloha, Silver Lake, Hell Hole Reservoir, French Meadow Reservoir, Lake Spaulding, and others. The extent of the impacts that these projects have had on the mountain yellow-legged frog is not known. The construction of dams probably has affected mountain yellow-legged frogs in the Sierra Nevada by altering their habitat and movements, and also by altering the distribution of predators (reservoirs are often stocked with nonnative fish species that incidentally prey on mountain yellow-legged frogs (See Predation, Factor C, below)). Mountain yellow-legged frogs cannot live in or move through the exposed shorelines created by reservoirs, nor can they successfully reproduce in these environments with predatory fishes unless there are shallow side channels or disjunct pools that are free of predatory fishes (Jennings 1996, p. 939).

Dams may alter the temperature and sediment load of the rivers they impound (Cole and Landres 1996, p. 175). Dams, water diversions, and their associated structures can alter the natural flow regime with unseasonal and fluctuating releases of water, create habitat conditions unsuitable for native amphibians both upstream and downstream of dams, and act as barriers to movements by dispersing juvenile and migrating adult amphibians (Jennings 1996, p. 939).

Where dams act as barriers to mountain yellow-legged frog movement, they would effectively prevent genetic exchange between populations and the recolonization of sites. Water diversions that remove water from mountain yellow-legged frog habitat may adversely impact breeding success and adult survivorship if the diversion results in a lowering of the water level to the extent that the entire water column freezes in the winter, or to the extent that the habitat is rendered dry. These factors are likely to have contributed to the decline of mountain yellow-legged frogs and probably continue to pose a risk to the species.

### *Roads and Timber Harvest*

Any activity that severely alters the terrestrial environment, including road construction and timber harvest, is likely to result in the reduction and extirpation of amphibian populations in the Sierra Nevada (Jennings 1996, p. 538). Most of the mountain yellow-legged frog populations are in areas such as national parks or designated wilderness areas where timber is not harvested (Bradford *et al.* 1994a, p. 323; Drost and Fellers 1996, p. 421; Knapp and Matthews 2000, p. 430). Some of these populations and others outside of these areas, are located at too high an altitude for timber to be harvested, so this activity is not expected to affect the majority of extant mountain yellow-legged frog populations. There are some mountain yellow-legged frog populations in areas where timber harvests have occurred in the past and others where it may occur in the future. There are also roads within the range of the mountain yellow-legged frog; however, neither of these factors has been implicated as an important contributor to the decline of this species (Jennings 1996, pp. 921–941).

Timber harvests remove vegetation and cause ground disturbance and compaction, which makes the ground more susceptible to erosion (Helms and Tappeiner 1996, p. 446). This erosion causes increases in siltation downstream that could potentially damage mountain yellow-legged frog breeding habitat and lower the water table, which may dry riparian habitats used by mountain yellow-legged frogs. The majority of erosion caused by timber harvests is from logging roads (Helms and Tappeiner 1996, p. 447). Prior to the formation of National Parks in 1890, and National Forests in 1905, timber harvest was widespread and unregulated, but primarily took place at low elevations on the west slope of the Sierra Nevada below the elevational range of the mountain yellow-legged frog (UC 1996b, pp. 24–25). Between 1900 and 1950, the majority of timber harvest was of old growth forests on private land (UC 1996b, p. 25). Between 1950 and the early 1990s, there were increases in timber harvest on national forests, and the majority of timber harvest-associated impacts on mountain yellow-legged frogs may have taken place during this period.

Roads, including those associated with timber harvests, can contribute to the fragmentation of forests and limit amphibian movement, thus having a negative effect on amphibian species richness (Lehtinen *et al.* 1999, pp. 8–9; deMaynadier and Hunter 2000, p. 56). Roads also create the potential for direct mortality of amphibians caused by vehicles (deMaynadier and Hunter 2000, p. 56) and the possible introduction of contaminants.

## *Fire Management Activities*

Mountain yellow-legged frogs are generally found at high elevations in wilderness areas and national parks where vegetation is sparse and fire suppression activities are implemented infrequently. Potential impacts to the species resulting from fire management activities include: water drafting (taking of water) from occupied ponds and lakes, resulting in direct mortality or rendering the habitat unsuitable for reproduction and survivorship; construction of fuel breaks either by hand or heavy equipment, potentially resulting in erosion and siltation of habitat; fire suppression with water applications or fire retardants; and increased human activity in the area, potentially disrupting mountain yellow-legged frog behavior.

Fire retardant chemicals contain nitrogen compounds and/or surfactants (a subset of chemical additives usually used to facilitate application). Laboratory tests of these chemicals have shown that they can cause mortality in fishes and aquatic invertebrates by releasing surfactants and ammonia when they are added to water (Hamilton *et al.* 1996, pp. 1–2), and similar effects are likely on amphibians. Therefore, if fire retardant chemicals were dropped in or near mountain yellow-legged frog habitat, they could have negative effects on individuals.

In some areas within the range of the mountain yellow-legged frog, long-term fire suppression has changed forest structure and conditions where fire severity and intensity are higher (McKelvey *et al.* 1996, pp. 1934–1935). Prescribed fire has been used by land managers to achieve various silvicultural objectives, including the reduction of fuel loads. In some systems, fire is thought to be important in maintaining open aquatic and riparian habitats for amphibians (Russell *et al.* 1999, p. 378). But severe and intense wild fires may reduce the ability of amphibians to survive such a fire. However, amphibians display adaptive behavior that may minimize mortality from fire, by taking cover in wet habitats or taking shelter in subterranean burrows, though the moist and permeable skin of amphibians increases their susceptibility to heat and desiccation (Russell *et al.* 1999, p. 374). Neither the direct nor indirect effects of prescribed fire or wildfire on the mountain yellow-legged frog have been studied, but because the species generally occupies high elevation habitat, fire is not a likely risk to this species in much of its range.

In summary, historic grazing activities likely modified the habitat of the mountain yellow-legged frog throughout its range. Although grazing pressure has been significantly reduced from historic levels, grazing may continue to contribute to localized degradation and loss of suitable habitat, negatively affecting mountain yellow-legged frog populations. The effects of recreation, dams, water diversions, roads, timber harvests, and fire management activities on the mountain yellow-legged frog are not well studied, and though they may have negatively affected mountain yellow-legged frogs and their habitat, they have not been implicated as primary factors in the decline of this species (Bradford *et al.* 1993, pp. 882–888; Bradford *et al.* 1994a, p. 326; Jennings 1996, pp. 938–941; Knapp and Matthews 2000, pp. 436–437). However, recreation, dams, water diversions, roads, timber harvests, and fire management activities may be factors of secondary importance in the decline of the mountain yellow-legged frog and the modification of its habitat (Jennings 1996, pp. 938–941).

*B. Overutilization for commercial, recreational, scientific, or educational purposes.* There is no known commercial market for mountain yellow-legged frogs, nor are there documented recreational or educational uses for mountain yellow-legged frogs. The mountain yellow-legged frog does not appear to be particularly popular among amphibian and reptile collectors; however, Federal listing could raise the value of the animals within wildlife trade markets and increase the threat of unauthorized collection above current levels (McCloud 2002, pers. com). Even limited interest in the species could pose a serious threat to this animal.

Scientific research may cause stress to mountain yellow-legged frogs through disturbance, including disruption of the species' behavior, handling individuals, and injuries associated with marking and tracking individuals. Scientific research has also resulted in the death of numerous individuals through the collection of museum specimens (Zweifel 1955, p. 207; Jennings and Hayes 1994, pp. 74–78). However, this is a relatively minor threat. Of greater concern is the possibility that researchers may be contributing to the spread of pathogens via clothing and sampling equipment as they move between water bodies and populations (Bradford *et al.* 1994a, p. 326; Fellers *et al.* 2001, p. 952). Given the uncertainty surrounding the potential for researchers to contribute to the spread of pathogens, researchers implement equipment sterilization procedures between survey sites (Eddinger 2002, p. 3; Knapp 2002a, p. 34; Vredenburg 2002, 11). For further discussion concerning the threat of disease, see Factor C below.

### *C. Disease or predation.*

#### *Predation*

Native predators of mountain yellow-legged frogs include the mountain garter snake (*Thamnophis elegans elegans*), Brewer's blackbird (*Euphagus cyanocephalus*), Clark's nutcrackers (*Nucifraga columbiana*), coyotes (*Canis latrans*), and black bear (*Ursus americanus*) (Mullally and Cunningham 1956, p. 193; Bradford 1991, pp. 176–177; Jennings *et al.* 1992, p. 505; Feldman and Wilkinson 2000, p. 102; Vredenburg *et al.* 2005, p. 565).

Predation by introduced trout is the best-documented cause of the decline of the Sierra Nevada mountain yellow-legged frog, because it has been repeatedly observed that nonnative fishes and mountain yellow-legged frogs rarely co-exist (Grinnell and Storer 1924, p. 664; Mullally and Cunningham 1956, p. 190; Cory 1962a, p. 401, 1963, p. 172; Bradford 1989, pp. 775–778; Bradford and Gordon 1992, p. 65; Bradford *et al.* 1993, pp. 882–888, 1994a, p. 326, 1998; Drost and Fellers 1996, p. 422; Jennings 1996, p. 940; Knapp 1996, p. 14; Knapp and Matthews 2000, p. 428; Knapp *et al.* 2001, p. 401; Vredenburg 2004, 7649). The body of scientific research on the distributions of introduced trout and mountain yellow-legged frogs over time has conclusively demonstrated that introduced trout have negatively impacted mountain yellow-legged frogs over much of the Sierra Nevada (Bradford 1989, pp. 775–778; Bradford *et al.* 1993, pp. 882–888, 1998; Knapp 1994, p. 3, 1996, pp. 13–15; Drost and Fellers 1996, p. 422; Knapp and Matthews 2000, p. 428; Knapp *et al.* 2001, p. 401). Mountain yellow-legged frogs and trout (native and nonnative) do co-occur at some sites, but these co-occurrences probably are

mountain yellow-legged frog populations with negative population growth rates in the absence of immigration (Bradford *et al.* 1998, p. 2489; Knapp and Matthews 2000, p. 436). Nonnative fish stocking programs have been recognized to have negative ecological implications because nonnative fish eat native aquatic flora and fauna, including amphibians and invertebrates (Bahls 1992, p. 191; Erman 1996, p. 992; Matthews *et al.* 2001, pp. 1135–1136; Pilliod and Peterson 2001, p. 329; Schindler *et al.* 2001, p. 309; Moyle 2002, p. 58).

Prior to extensive trout planting programs in the late 19th Century through the present, most streams and lakes in the Sierra Nevada at elevations above 1,800 m (6,000 ft) were without fishes. Several native fish species occur naturally in aquatic habitats below this elevation around the Sierra Nevada (Knapp 1996, pp. 12–14; Moyle *et al.* 1996, p. 354; Moyle 2002, p. 25). Natural barriers prevented fish from colonizing the higher elevation headwaters of the Sierra Nevada watershed (Moyle *et al.* 1996, p. 354). The upper reaches of the Kern River where native fish such as the Little Kern golden trout (*Oncorhynchus mykiss whitei*) evolved, represents the only major exception to the 1,800 m (6,000 ft) elevational limit for fishes within the range of the mountain yellow-legged frog in the Sierra Nevada (Moyle 2002, p. 25).

With the Gold Rush and its associated increase in human habitation and habitat alteration, fish distribution and species composition began to change dramatically in high elevation lakes and streams (Moyle *et al.* 1996, p. 356). Some of the first practitioners of trout stocking in the Sierra Nevada were the Sierra Club, local sportsmen's clubs, private citizens, and the U.S. military (Knapp 1996, p. 8; Pister 2001, p. 280). As more hatcheries were built and distribution of nonnative fish became better organized under State agency leadership, trout continued to be planted for the purpose of increased angler opportunities and success (Pister 2001, p. 281). After World War II, the method of transporting trout to be stocked in high elevation areas changed from packstock to aircraft, which allowed stocking in more remote lakes and in greater numbers. It was at this point that CDFG began managing the bulk of the program, as it does today (Knapp 1996, p. 8; Pister 2001, p. 281).

Brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and other trout species assemblages have been planted in most streams and lakes of the Sierra Nevada (Knapp 1996, p. 8; Moyle 2002, p. 25). National forests in the Sierra Nevada have a higher proportion of lakes with nonnative fish occupancy than do national parks (Knapp 1996, p. 3). This is primarily because the NPS adopted a policy that greatly reduced fish stocking within their jurisdictional boundaries in the late 1970s. Fish stocking was terminated altogether in Sierra Nevada national parks in 1991 (Knapp 1996, p. 9).

Knapp's (1996, pp. 1–44) review of previous trout distribution estimates and other available data on trout distribution in the Sierra Nevada indicated that approximately 63 percent of lakes larger than 1 ha (2.5 ac) contain one or more nonnative trout species, and as many as 85 percent of lakes larger than 1 ha (2.5 ac) within national forests currently contain fish. Lakes larger than 1 ha (2.5 ac) within Sierra Nevada national parks were estimated to have from 35 to 50 percent nonnative fish occupancy, a 29 to 44 percent decrease since fish stocking was terminated (Knapp 1996, p. 1). Though data on fish occupancy in streams is lacking throughout



the Sierra Nevada, Knapp (1996, p. 11) estimated 60 percent of the streams in Yosemite National Park were occupied by trout, despite the curtailment of stocking practices over 25 years ago. Grinnell and Storer (1924, p. 664) observed that fish stocking in Yosemite National Park “nearly or quite eliminates the (mountain yellow-legged) frogs.”

The most spatially comprehensive study of introduced fish and mountain yellow-legged frog distributions included an analysis of large landscapes affected by different fish stocking regimes, watersheds with differing trout distributions, and individual water bodies with varying fauna assemblages (Knapp and Matthews 2000, p. 435). The Knapp and Matthews (2000, p. 428) study on the effects of introduced fishes on the mountain yellow-legged frog in the Sierra and Inyo National Forests’ John Muir Wilderness indicated 65 percent of water bodies 1 ha (2.5 ac) or larger were stocked with fishes on a regular basis up through the time of the study. Over 90 percent of the total water body surface area in the John Muir Wilderness in the Sierra and Inyo National Forests is occupied by nonnative trout (Knapp and Matthews 2000, p. 434). All fish stocking was terminated in 1977 in the adjacent Kings Canyon National Park. Knapp and Matthews (2000, p. 428) surveyed all lakes and ponds, more than 1,700 water bodies, for fishes and mountain yellow-legged frogs. They concluded that a strong negative correlation exists between introduced trout and mountain yellow-legged frogs across the landscape, the watersheds, the individual water bodies of the study area, and possibly throughout the Sierra Nevada (Knapp and Matthews 2000, p. 435). Consistent with this finding are the results of an analysis of the distribution of mountain yellow-legged frog larvae that indicates that the presence and abundance of larvae are reduced dramatically in lakes that have fish as compared with lakes that were never stocked with fish (Knapp *et al.* 2001, p. 408).

Knapp (2005a, p. 265–279) also statistically compared the distribution of nonnative trout with the distributions of several amphibian and reptile species in 2239 lakes and ponds in Yosemite National Park. He found that mountain yellow-legged frogs were five times less likely to be detected in waters where trout had been detected. Even though stocking within the national park ceased in 1991, more than 50 percent of water bodies deeper than 4 m and 75 percent deeper than 16 m, contained trout populations in 2000–2002 (Knapp 2005a, p. 270). Both trout and mountain yellow-legged frogs were more likely to be detected in deeper water bodies, so it appears that nonnative trout are excluding mountain yellow-legged frogs from some of the best aquatic habitats.

Several aspects of the mountain yellow-legged frog’s life history may exacerbate its vulnerability to predation and extirpation by nonnative trout (Bradford 1989, pp. 777–778; Bradford *et al.* 1993, pp. 886–888; Knapp 1996, p. 14; Knapp and Matthews 2000, p. 435). Mountain yellow-legged frogs are aquatic and are found mainly in lakes. This increases the probability that they will encounter nonnative fishes whose distribution has been greatly expanded throughout the Sierra Nevada as a result of fish stocking. The multiple-year larval stage of the mountain yellow-legged frog necessitates their use of permanent water bodies that are deep enough so as not to freeze, and so that overwintering adults can avoid oxygen depletion when the water is covered by ice (Mullally and Cunningham 1956, p. 194; Bradford 1983, p. 1179; Knapp and Matthews 2000, pp. 435–436). This further restricts larvae to water bodies

suitable for and frequently inhabited by fishes (Knapp 1996, p. 14) and isolates mountain yellow-legged frogs to fishless marginal habitats (Bradford *et al.* 1993, 886–887; Knapp and Matthews 2000, p. 435).

Mountain yellow-legged frog populations have also been extirpated at some fishless bodies of water (Bradford 1991, p. 176; Drost and Fellers 1996, p. 422). An explanation suggested for recent mountain yellow-legged frog population declines from fishless waters in the Sierra Nevada is the isolation and fragmentation of remaining populations by introduced fishes in the streams, which once provided the mountain yellow-legged frog with dispersal and recolonization routes (Bradford 1991, p. 176; Bradford *et al.* 1993, p. 887). Based on a survey of 95 basins within Sequoia and Kings Canyon National Parks, Bradford *et al.* (1993, pp. 885–886) calculated that the introduction of fishes into the study area resulted in approximately a ten-fold decrease in hydrologic connectivity between populations of mountain yellow-legged frogs. Knapp and Matthews (2000, p. 436) believe that this has generally restricted mountain yellow-legged frogs to extremely isolated and marginal habitat. Trout influenced the isolation and fragmentation of mountain yellow-legged frog populations and metapopulations, making them more vulnerable to extirpation from random events (such as disease) than large, unfragmented metapopulations (Wilcox 1980, pp. 114–115; Hanski and Simberloff 1997, p. 21; Bradford *et al.* 1993, p. 887; Knapp and Matthews 2000, p. 436). Given the metapopulation structure of the mountain yellow-legged frog, these isolated population locations may have higher extinction rates than colonization rates because trout may prevent successful recolonization and dispersal to and from these sites (Bradford *et al.* 1993, p. 887; Blaustein *et al.* 1994a, p. 7; Knapp and Matthews 2000, p. 436). In addition, amphibians may not recolonize unoccupied sites following local extinctions because of physiological constraints; the tendency for amphibians, including the mountain yellow-legged frog, to move only short distances; and high site fidelity (Blaustein *et al.* 1994a, p. 8).

Knapp and Matthews (2000, p. 436) suggest that the predation of mountain yellow-legged frogs by fishes as observed in the early 20<sup>th</sup> Century by Grinnell and Storer and the documented declines of the 1970s (Bradford 1991, pp. 174–177; Bradford *et al.* 1994a, pp. 323–327; Stebbins and Cohen 1995, pp. 226–227), are not the start of the mountain yellow-legged frog's decline, but rather the end of a long decline that started soon after fish introductions to the Sierra Nevada began in the mid-1800s. Knapp and Matthews (2000, p. 436) note that metapopulation theory (Hanski 1997, pp. 85–86) predicts this type of time lag from habitat modification to population extinction.

Fish-induced declines of the mountain yellow-legged frog may be reversed in some locations with an intensive and focused effort to restore fishless conditions (Knapp and Matthews 1998, p. 207, 2000, p. 437; Knapp *et al.* 2001, p. 418; Knapp *et al.* 2007a, p. 17). Removing fish from lakes with an adjacent source population of mountain yellow-legged frogs can result in the rapid recolonization of the lake by the species and, over time, may result in recovery to conditions similar to lakes that had never been stocked (Knapp *et al.* 2001, p. 418; Briggs *et al.* 2002, p. 37; Knapp 2002a, p. 25; Knapp *et al.* 2007a, p. 18). Trout removal from several lakes has been successfully accomplished in the Sierra National Forest's John Muir Wilderness. This

has resulted in the natural recolonization and initial recovery of mountain yellow-legged frogs in one of the lakes where trout were removed (Knapp 2002a, p. 25). In the other two lakes within this basin where trout were removed, mountain yellow-legged frogs were successfully reintroduced, and there is evidence of reproduction in these translocated populations (Knapp 2002a, p. 25). Sequoia and Kings Canyon National Parks have initiated a mountain yellow-legged frog restoration project which employs gill nets and electrofishing to remove fish from select lakes and adjacent stream segments at sites with little to no human visitation (NPS 2001, pp. 13–14). In areas of John Muir Wilderness and Kings Canyon National Park, fish removal resulted in large numbers of recolonizing nearby fishless habitat Knapp *et al.* 2007a, p. 17). However, because of the cumulative effect of past mountain yellow-legged frog population declines (upwards of 80 percent in the 20th century), and ongoing population declines caused by disease or other factors, the recolonization of lakes restored to fishless conditions will grow less likely as the number of viable source populations of mountain yellow-legged frogs dwindles (Knapp *et al.* 2001, p. 18).

The best-documented cause of the decline of the mountain yellow-legged frog is the introduction of nonnative fish (Bradford 1989, pp. 775–778; Bradford *et al.* 1993, pp. 882–888; Knapp and Matthews 2000, p. 435). In summarizing the effects of nonnative fish on the mountain yellow-legged frog, it is important to recognize that: (1) the vast majority of the range of the mountain yellow-legged frog did not evolve with any species of fish as this frog predominantly occurs in water bodies above natural fish barriers; (2) water bodies throughout the range of the mountain yellow-legged frog have been intensively stocked with nonnative fish, and where stocking has terminated, self-sustaining fish populations continue to persist; (3) the multiple year larval stage of the mountain yellow-legged frog prevents successful recruitment to populations that co-occur with nonnative fish because when water bodies ice over in winter, larvae are forced from shallow margins of lakes and ponds into deeper unfrozen water where they are vulnerable to predation by nonnative fish; (4) adult mountain yellow-legged frogs that co-occur with nonnative fish are vulnerable to predation when they are exposed to these fish, such as when adult mountain-yellow legged frogs overwinter at the bottom of deep water bodies; and (5) the introduction of nonnative fish has fragmented mountain yellow-legged frog habitat, isolated populations from each other, and generally restricted remaining mountain yellow-legged frog populations to marginal habitats, thereby increasing the likelihood of localized extinctions without the possibility of recolonization.

In a recent study, from 1996 to 2003, introduced trout were removed from 5 lakes in a remote area of the Sierra Nevada, with 16 nearby lakes used as controls; 8 with introduced trout and 8 without introduced trout (Vredenburg 2004, p. 7647). The study experimentally manipulated the presence and absence of rainbow trout and brook trout to test the hypothesis that these fish have contributed to the decline of the mountain yellow-legged frog. The experiment concluded that introduced trout are effective predators on mountain yellow-legged frog tadpoles, and suggested that “(i) that the introduction of trout is the most likely mechanism responsible for the decline of this mountain frog and (ii) that these negative effects can be reversed.”

To help reverse the decline of the mountain yellow-legged frog, the Sequoia and Kings Canyon National Parks have been removing introduced trout since 2001, and efforts are ongoing (Boiano 2009, pers. com.). Over 18,000 introduced trout have been removed from 11 lakes and some adjacent streams since the project started in 2001. The lakes range from completely fish-free to mostly fish-free and substantial mountain yellow-legged frog population increases have resulted (Knapp *et al.* 2001, pp 16–17). The CDFG has also removed or is in the process of removing nonnative trout from a total of between 10 and 20 water bodies in the Inyo, Humboldt-Toiyabe, Sierra, and El Dorado National Forests. In the El Dorado National Forest golden trout were removed from Leland Lakes, and attempts have been made to remove trout from two sites near Gertrude Lake and a tributary of Cole Creek (Lehr 2005, pers. com.), as well as from three lakes in the Pyramid Creek watershed; no data showing increase in mountain yellow-legged frogs at these sites was available. Additionally, the Forest Service's Lake Tahoe Basin Management Unit has begun fish removal from three high elevation lakes within the Desolation Wilderness (Muskopf 2009, p. ).

### *Disease*

Studies suggest that pathogen-related causes have resulted in amphibian population declines and mass die-offs worldwide (Bradford 1991, pp. 174–177; Blaustein *et al.* 1994b, pp. 251–254; Alford and Richards 1999, pp. 506; Muths, *et al.* 2003, p. 357; Weldon *et al.* 2004, p. 2100; Rachowicz *et al.* 2005, p. 1446). One pathogen which has been strongly associated with dramatic declines on all five continents is the chytrid fungus, *Batrachochytrium dendrobatidis* (Rachowicz *et al.* 2005, 1442). Recent research has shown that this pathogenic fungus is widely distributed throughout the Sierra Nevada, and that infected mountain yellow-legged frogs die soon after metamorphosis (Knapp 2005b; Rachowicz 2005, pers. com.; Rachowicz *et al.* 2006, p. 1671). Rachowicz *et al.* (2006, p. 1671) monitored several infected and uninfected populations in Sequoia and Kings Canyon National Parks over multiple years, documenting dramatic declines and extirpations in infected but not in uninfected populations. In the summer of 2005, 39 of 43 populations assayed in Yosemite National Park were positive for chytrid fungus (Knapp 2005b, pers. com.).

In California, chytridiomycosis, more commonly known as chytrid fungus, has been detected in many amphibian species, including the mountain yellow-legged frog (Fellers and Green, as cited in Briggs *et al.* 2002, p. 38; Knapp 2002b, p. 1). Fellers *et al.* (2001, pp. 950–951) report the presence of several bacteria and chytrid fungus in larval and recently metamorphosed mountain yellow-legged frogs from sites within the Sierra Nevada. Chytrid fungus affects the keratinized (horny epidermal tissue) mouth parts and epidermal tissue of larvae and metamorphosed mountain yellow-legged frogs (Fellers *et al.* 2001, pp. 950–951). Though little is known about its life history in the Sierra Nevada, chytrid fungus has a simple asexual life cycle, and chytrids can generally withstand adverse conditions such as freezing or drought (Briggs *et al.* 2002, p. 38). A research effort is underway to study the dynamics of this pathogen and the mountain yellow-legged frog within the Sierra Nevada (Briggs *et al.* 2002, p. 36–70). Adult frogs can acquire this fungus from tadpoles and it can be transmitted between tadpoles (Rachowicz and Vredenburg 2004, p. 80). The mountain yellow-legged frog may be especially

vulnerable to infections of chytrid fungus because all life stages share the same habitat nearly year-round, facilitating the transmission of this fungus among individuals at different life stages (Fellers *et al.* 2001, p. 951).

Survey results from 2000 in Yosemite and Sequoia–Kings Canyon National Parks indicate 24 percent of the mountain yellow-legged frog populations showed signs of chytrid infection (Briggs *et al.* 2002, p. 40). In both 2003 and 2004, 19 percent of assayed populations in Sequoia and Kings Canyon National Parks were infected with chytrid fungus (Rachowicz 2005, pp. 2-3). In 2005, 91 percent of assayed populations in Yosemite National Park showed evidence of chytrid infection (Knapp 2005b, pp. 1-2). In mountain yellow-legged frogs, chytrid fungus has been observed to result in overwinter mortality and mortality during metamorphosis (Briggs *et al.* 2002, p. 39; Rachowicz 2005, pp. 2-3). Effects of chytrid fungus on host populations of the mountain yellow-legged frog are variable, ranging from extinction, persistence with a high level of infection, to persistence with low levels of infection (Briggs *et al.* 2002, pp. 40–41). Studies of the microscopic structure of tissue and other evidence suggests chytrid fungus caused many of the recent extinctions in the Sierra National Forest’s John Muir Wilderness Area and in Kings Canyon National Park, where 41 percent of the populations went extinct between 1995 and 2002 (Knapp 2002a, p. 10). In 2004, two of the 31 mountain yellow-legged frog populations in the Sixty Lake Basin of Kings Canyon National Park tested positive for chytrid fungus. Since then, all 31 populations have tested positive for this disease and 13 of the 31 have been extirpated (Vredenburg 2008, p. 1).

Chytrid fungus affecting wild frog populations was not documented until the late 1990s. Since then, it has been reported in amphibian populations worldwide (Fellers *et al.* 2001, p. 945; Rachowicz *et al.* 2005, p. 1442). Grinnell and Storer reported observations of “red-leg” disease in some mountain yellow-legged frog populations in Yosemite National Park Mountain. Red-leg disease is caused by the bacterial pathogen, *Aeromonas hydrophila* which causes the disease commonly known as “red-leg”. Bradford (1991, p. 175–179p) suggested that one such outbreak was a result of overcrowding within a mountain yellow-legged frog population. Though it is opportunistic and successfully attacks immuno-suppressed individuals, this pathogen appears to be highly contagious, affecting the epidermis and digestive tract of otherwise healthy amphibians (Shotts 1984, p. 51–52; Carey 1993, p. 358; Carey and Bryant 1995, pp. 14–15). In recent observations, red-leg disease is typically a secondary infection following a chytrid infection.

Visual examination of 43 mountain yellow-legged frog tadpole specimens collected between 1955 and 1976 revealed no suggestion of chytrid infection, but 14 of 36 specimens preserved between 1993 and 1999 had abnormalities attributable to the chytrid fungus (Fellers *et al.* 2001, p. 947). Since at least 1976, chytrid fungus has affected adult Yosemite toads (Green and Sherman 2001, p. 92). The Yosemite toad is sympatric (their ranges overlap) with the mountain yellow-legged frog. Therefore, it is possible that this pathogen has affected both of these amphibian species since at least the mid-1970s. Chytrid fungus is only a recently detected pathogen in amphibian populations; this may be an emerging infectious disease. How it has been transmitted to the mountain yellow-legged frog is unclear (Briggs *et al.* 2002, p. 39).

Other diseases have also been reported as adversely affecting other species of amphibians and may be present within the range of the mountain yellow-legged frog. *Saprolegnia* is a globally distributed fungus that commonly attacks all life stages of fishes (especially hatchery reared fishes), and has recently been documented to attack and kill egg masses of western toads (*Bufo boreas*) (Blaustein *et al.* 1994b, p. 252). This pathogen may be introduced through fish stocking or it may already be established in the aquatic ecosystem. Fishes and/or migrating or dispersing amphibians may be a vector for this fungus (Blaustein *et al.* 1994b, p. 253; Kiesecker *et al.* 2001, p. 1068). *Saprolegnia* has not been reported in the mountain yellow-legged frog; however, if hatchery fishes are vectors of this disease, it may have been introduced via fish stocking into historically occupied mountain yellow-legged frog habitat.

No viruses were detected in the mountain yellow-legged frogs that Fellers *et al.* (2001, p. 950) analyzed for chytrid fungus. In Kings Canyon National Park, Knapp (2002a, p. 20) found mountain yellow-legged frogs showing symptoms preliminarily attributed to a ranavirus. Mechanisms for disease transmission to the mountain yellow-legged frog remain unknown. However, Mao *et al.* (1999, pp. 49–50) isolated identical iridoviruses from wild co-occurring populations of the threespine stickleback (*Gasterosteus aculeatus*) and the red-legged frog (*Rana aurora*), indicating that infection by a given virus is not limited to a single species, and that iridoviruses can infect animals belonging to different taxonomic classes. This suggests that if virus-hosting trout are introduced into mountain yellow-legged frog habitat, they may be a vector of amphibian viruses.

Whether amphibian pathogens in the high Sierra Nevada have always coexisted with amphibian populations or if their presence is a recent phenomenon is uncertain; however, it has been suggested that the susceptibility of amphibians to pathogens may have recently increased in response to anthropogenic (human-caused) environmental disruption (Carey 1993, pp. 355–360; Blaustein *et al.* 1994b, p. 253; Carey *et al.* 1999, p. 7). This hypothesis suggests that environmental changes may be indirectly responsible for certain amphibian die-offs by immune system suppression of larval or postmetamorphic amphibians to the extent that they are not resistant to diseases (Carey 1993, p. 358; Blaustein *et al.* 1994b, p. 253; Carey *et al.* 1999, p. 7–8). Pathogens such as red-leg disease, which are present in fresh water and in healthy organisms, may erupt, potentially causing localized amphibian population die-offs when the immune system of individuals within the host population are suppressed (Carey 1993, p. 358; Carey and Bryant 1995, p. 14). Wind-borne pesticides from upwind agriculture potentially contribute to contaminant concentrations that may be high enough to compromise amphibian immune systems (Carey *et al.* 1999, pp. 8–10). Recreationists may contribute to the spread of pathogens between water bodies and populations via clothing and fishing equipment. Given the uncertainty surrounding the potential for researchers to contribute to the spread of pathogens, they have begun to implement equipment sterilization procedures between survey sites (Eddinger 2002, p. 3; Knapp 2002a, p. 34; Vredenburg 2002, p. 11).

A compounding effect of disease-caused extinctions of mountain yellow-legged frogs is that recolonization may never occur, because streams connecting extirpated sites to extant populations now contain introduced fishes, which act as barriers to frog movement within

metapopulations. This isolates the remaining populations of mountain yellow-legged frogs from each other (Bradford 1991, p. 176; Bradford *et al.* 1993, p. 887).

In summary, mountain yellow-legged frogs are vulnerable to multiple pathogens, whose effects range from population persistence, with low levels of infection within populations, to extinction of entire populations. Little is understood about many of these pathogens, making disease difficult to manage without a better understanding of their life histories and modes of transmission. Red-leg disease and chytrid fungus have been identified as having potentially catastrophic effects (localized extinction) on mountain yellow-legged frog populations. Though chytrid fungus was only recently discovered to affect amphibians (including the mountain yellow-legged frog), chytrid currently appears to have the highest rate of infection relative to other pathogens in mountain yellow-legged frog populations. The negative consequences of chytrid infection to mountain yellow-legged frog populations may be exacerbated by the fragmentation and isolation of remaining mountain yellow-legged frog metapopulations and populations due to nonnative fish introductions. This is because there may not be an adjacent mountain yellow-legged frog population with habitat connectivity that is able to recolonize an area following a pathogen-caused extinction event.

*D. The inadequacy of existing regulatory mechanisms.* Existing regulatory mechanisms that could provide some protection for the mountain yellow-legged frog in the Sierra Nevada include: (1) Federal laws and regulations; (2) State laws and regulations; and (3) local land use processes and ordinances. However, these regulatory mechanisms have not prevented nonnative fish introductions, pathogen outbreaks, and habitat modifications, all of which result in population declines of mountain yellow-legged frogs in the Sierra Nevada.

#### *Federal*

In response to the overgrazing by livestock of the available rangelands from the 1800s to the 1930s and the subsequent years of the Dust Bowl, Congress passed the Taylor Grazing Act in 1934. This was an effort to stop the damage to the remaining public lands from overgrazing and soil depletion, to provide for an order to grazing on public lands, and to attempt to stabilize the livestock industry using these lands (Meehan and Platts 1978, p. 275; *Public Lands Council et al. v. Babbitt Secretary of the Interior et al.* (167 F. 3d 1287)). Although passage of the Taylor Grazing Act resulted in reduced grazing in some areas, it did not reduce grazing severity, as use remained high, and it did not allow regeneration of many meadow areas (Beesley 1996, p. 14; Menke *et al.* 1996, p. 14; *Public Lands Council et al. v. Babbitt Secretary of the Interior et al.* (167 F. 3d 1287)). The Taylor Grazing Act of 1934, as amended, did initiate some grazing reform, possibly lessening impacts of livestock grazing on many species and populations of wild plants and animals, including the mountain yellow-legged frog and its habitat. However, it does not have any provisions specific to the protection of either the mountain yellow-legged frog or its habitat.

The Multiple-Use Sustained-Yield Act of 1960 (MUSY), as amended, provided direction that the national forests be managed using principles of multiple use and to produce a sustained

yield of products and services. Specifically, MUSY gives policy that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, wildlife, and fish purposes. Land management for multiple uses has inherent conflicts. However, MUSY directs resource management not to impair the productivity of the land while giving consideration to the relative values of the various resources, though not necessarily in terms of the greatest financial return or unit output. This act provides direction to the USFS that wildlife (which includes the mountain yellow-legged frog), is a value that must be managed for, though discretion is given to each national forest when considering the value of the mountain yellow-legged frog relative to the other uses for which they must manage. MUSY does not have any provisions specific to the protection of either the mountain yellow-legged frog or its habitat.

The Federal Land Policy and Management Act of 1976 (FLPMA), as amended, gives management direction to the Bureau of Land Management (BLM); however, its application is to all Federal lands, including those managed by the USFS. FLPMA includes a provision requiring that 50 percent or \$10,000,000 per year, whichever is greater, of all moneys received through grazing fees collected on Federal lands (including the USFS-administered lands within the range of the mountain yellow-legged frog) be spent for the purpose of on-the-ground range rehabilitation, protection, and improvement. This includes all forms of rangeland betterment such as fence construction, water development, and fish and wildlife enhancement. Half of the appropriated amount must be spent within the national forest where such moneys were derived. FLPMA provides for some rangeland improvements intended for the long-term betterment of forage conditions and resulting benefits to wildlife, watershed protection, and livestock production. Land improvements initiated pursuant to FLPMA may have benefited the mountain yellow-legged frog and its habitat; however, some mountain yellow-legged frog habitat has continued to be destabilized and deteriorate due to livestock grazing on lands subject to FLPMA (Knapp 1993a, p. 1, 1993b, p. 1, 1994, pp. 1–3, 2002a, p. 29; Jennings 1995, p. 133, 1996, pp. 938–939). We are unaware of any USFS-initiated projects developed under FLPMA for the specific benefit of the mountain yellow-legged frog, and, if the USFS has conducted such projects, what effects they have had.

The Wilderness Act of 1964 established a National Wilderness Preservation System made up of federally owned areas designated by Congress as “wilderness” for the purpose of preserving and protecting designated areas in their natural condition. Commercial enterprise, road construction, use of motorized vehicles or other equipment, and structural developments are generally prohibited within designated wilderness. Livestock grazing is permitted within designated wilderness, subject to other applicable laws, if it was established prior to the passage of this act. The Wilderness Act does not specifically mention fish stocking although it does state that it shall not affect the jurisdiction or responsibilities of States with wildlife and fish responsibilities in the national forests. Whether fish stocking is permitted under the Wilderness Act is an issue that has been debated (Bahls 1992, p. 188; Landres *et al.* 2001, p. 287). However, it generally has not limited fish stocking in the Sierra Nevada (Knapp 1996, p. 19). Passage of the Wilderness Act has not positively affected mountain yellow-legged frog populations in wilderness areas of the Sierra Nevada as it does not prevent fish stocking (Knapp and Matthews 1996, p. 818, 2000, p. 429). Potentially, the Wilderness Act has helped to protect mountain



yellow-legged frog habitat from development or other types of habitat conversions and disturbances; however, mountain yellow-legged frog populations have continued to decline despite its passage.

The National Environmental Policy Act of 1969 (NEPA), as amended, requires all Federal agencies to formally document and publicly disclose the environmental impacts of all actions and management decisions. NEPA documentation is provided in an environmental impact statement, an environmental assessment, or a categorical exclusion, and may be subject to administrative appeal or litigation. The Pacific Southwest Region (Region 5) of the USFS considers the mountain yellow-legged frog a Forest Service sensitive species. Therefore, as part of USFS policy, the analysis related to planning under the National Forest Management Act of 1976 (NFMA) and conducted by the USFS to evaluate potential management decisions under NEPA includes a biological evaluation which discloses potential impacts to sensitive species at both the forest planning level and on a project-by-project basis. Under USFS policy (FSM 2620 and 2670), projects must not result in contributing to a trend towards Federal listing of species. The species' populations have continued to decline (Bradford *et al.* 1993, pp. 882–888, 1994a, pp. 323–327; Drost and Fellers 1996, p. 414; Jennings 1996, pp. 934–935; Knapp 1996, pp. 13–14) despite the analyses pursuant to NEPA on all Federal actions potentially affecting the mountain yellow-legged frog in the Sierra Nevada, and analyses pursuant to both NFMA and NEPA on national forests.

In the few cases where the Sierra Nevada mountain yellow-legged frog occurs in habitat occupied by species listed pursuant to the Act, the mountain yellow-legged frog may be afforded protection under this legislation. The native Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) and native Paiute cutthroat trout (*Oncorhynchus clarki seleneris*) are federally listed species, occurring predominantly in drainages on the east side of the Sierra Nevada. They co-occur with several small populations of mountain yellow-legged frogs at lower elevations on the edge of the species' range. The native Little Kern golden trout is a federally threatened species, co-occurring with the mountain yellow-legged frog in a few isolated locations in the southern Sierra Nevada. Recovery actions for these trout species, such as physical habitat protection, may benefit the mountain yellow-legged frog. For example, on the Tahoe National Forest, grazing, recreation, and other restrictions for the benefit of the Lahontan cutthroat trout and its habitat have been established. One of these measures that benefits the mountain yellow-legged frog is the establishment of a bank protection measure that allows for 10 percent bank disturbance (measured as bare ground accompanied by soil displacement and/or cutting of plant root crowns). Elsewhere the standard for bank disturbance is 20 percent (Carlson 2002a, p. 2). However, the use of chemicals or electrofishing to remove nonnative fish from threatened trout habitat may adversely affect mountain yellow-legged frogs present at the time of treatment. Additionally, listed native trout species may prey on the mountain yellow-legged frog at sites where they co-occur.

The Forest and Rangeland Renewable Resources Planning Act of 1974, as amended by NFMA, specifies that all national forests must have a land and resource management plan (LRMP). The purpose of the LRMP is to guide and set standards for all natural resource

management activities for the life of the plan (10 to 15 years) on each national forest. NFMA requires the USFS to incorporate standards and guidelines into LRMPs. This has historically been done through a NEPA process, including provisions to manage plant and animal communities for diversity, based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives. The 1982 planning regulations for implementing NFMA, under which all existing forest plans were prepared and which still guide management, also required that fish and wildlife habitat on national forest system lands “shall be managed to maintain viable populations of existing native and desired nonnative vertebrate species in the planning area. For planning purposes, a viable population is one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area. In order to insure that viable population will be maintained, habitat must be provided to support, at least, a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area.” Revised forest management regulations enacted in 2005, replace the requirement that viable populations of existing vertebrate species be maintained, with less specific guidance to “provide for ecological conditions to support a diversity of native plant and animal species in the plan area (USDA 2005, p. 1022).” These new regulations create the potential for reduced protection of the mountain yellow-legged frog within the national forests which constitute the majority of its range.

In 2001, a record of decision (ROD) was signed by the USFS for the Sierra Nevada Forest Plan Amendment (SNFPA), based on the final environmental impact statement (FEIS) for the SNFPA effort and prepared under the 1982 NFMA planning regulations. The ROD amends the USFS Pacific Southwest Regional Guide, the Intermountain Regional Guide, and the LRMPs for national forests in the Sierra Nevada and Modoc Plateau. This document affects land management on all national forests throughout the range of the mountain yellow-legged frog. The SNFPA addresses and gives management direction on issues pertaining to old forest ecosystems; aquatic, riparian, and meadow ecosystems; fire and fuels; noxious weeds; and lower westside hardwood ecosystems of the Sierra Nevada.

In January 2004, the USFS amended the SNFPA, based on the final supplemental environmental impact statement (FSEIS), following a review of specific areas of the SNFPA: fire and fuels treatments, compatibility with the National Fire Plan, compatibility with the Herger-Feinstein Quincy Library Group Forest Recovery Pilot Project, and effects of the SNFPA on grazing, recreation, and local communities. (USDA 2004a, pp. 26–30)

Relevant to the mountain yellow-legged frog, the FSEIS ROD for the SNFPA aims to protect and restore aquatic, riparian, and meadow ecosystems, and to provide for the viability of its associated native species via an aquatic management strategy. The aquatic management strategy is a general framework with broad policy direction. Implementation of this strategy is intended to take place at the landscape and project levels. There are nine goals associated with the aquatic management strategy. They include: (1) the maintenance and restoration of water quality to comply with the Clean Water Act (CWA) and the Safe Drinking Water Act; (2) the maintenance and restoration of habitat to support viable populations of native and desired

nonnative riparian-dependent species and to reduce negative impacts of nonnative species on native populations; (3) the maintenance and restoration of species diversity in riparian areas, wetlands, and meadows to provide desired habitats and ecological functions; (4) the maintenance and restoration of the distribution and function of biotic communities and biological diversity in special aquatic habitats (such as springs, seeps, vernal pools, fens, bogs, and marshes); (5) the maintenance and restoration of spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; (6) the maintenance and restoration of hydrologic connectivity between floodplains, channels, and water tables to distribute flood flows and to sustain diverse habitats; (7) the maintenance and restoration of watershed conditions as measured by favorable infiltration characteristics of soils and diverse vegetation cover to absorb and filter precipitation, and to sustain favorable conditions of stream flows; (8) the maintenance and restoration of instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats and to keep sediment regimes within the natural range of variability; and (9) the maintenance and restoration of the physical structure and condition of stream banks and shorelines to minimize erosion and sustain desired habitat diversity. If these goals are pursued and met, the mountain yellow-legged frog and its habitat could benefit. These goals, though broadly stated, include measures to reduce impacts of nonnative trout predation on mountain yellow-legged frogs as well as the resulting isolation of populations. These goals, if met, would also restore mountain yellow-legged frog aquatic habitats, including meadows, fens, stream banks, and shorelines that have been degraded by a history of livestock use.

To help meet these goals, the aquatic management strategy proposes a broad initial action to address the mountain yellow-legged frog in a conservation plan developed by the USFS with other State and Federal agencies; an effort by the USFS to do this is underway. Where known locations of mountain yellow-legged frogs occur on the national forests, critical aquatic refuges will be designated. A primary management goal for the critical aquatic refuges is to contribute to the viability and recovery of sensitive species (including the mountain yellow-legged frog) through habitat preservation, enhancement, restoration, or connectivity. Within the aquatic management strategy, critical aquatic refuges are given highest priority for evaluating how existing and proposed activities are consistent with the goals of the strategy. The aquatic management strategy directs existing and proposed activities within critical aquatic refuges to be consistent with the goals of the critical aquatic refuges. This evaluation will be made using the riparian conservation objectives and associated standards and guidelines, as defined in the FSEIS ROD for the SNFPA. One such standard and guideline specific to the mountain yellow-legged frog includes the avoidance of pesticide applications from within 152 m (500 ft) of sites known to be occupied by the species.

Management standards and guidelines in the SNFPA FSEIS ROD for the Yosemite toad may impact the mountain yellow-legged frog in areas where these two species overlap. Standards and guidelines excluding livestock from standing water and saturated soils in wet meadows and associated streams and springs occupied by Yosemite toads during the breeding and rearing season can be waived if a site specific management plan is developed. Consequently, the waiver

may affect the mountain yellow-legged frog if they are present in the area. Additionally, these grazing restrictions do not apply to packstock or saddlestock (USDA 2004b, p. 10).

The SNFPA includes requirements for monitoring to determine how well the aquatic management strategy goals and the riparian conservation objectives have been met, and how closely management standards and guidelines have been applied.

Our review of the SNFPA FEIS and ROD indicate that full implementation of the SNFPA FSEIS could have both positive and negative effects to the mountain yellow-legged frog and its habitat. National forests affected by the SNFPA are responsible for implementing it; however, implementation is subject to funding. Therefore, the extent to which it may benefit the mountain yellow-legged frog and its habitat is uncertain. There is additional uncertainty because the proposed changes to the NFMA planning regulations recently issued by Forest Service (67 FR 72770) contain two options for meeting the NFMA direction to provide for the diversity of plant and animal communities, and both options would change the current regulation pertaining to forest planning to provide habitat to support viable populations.

### *State*

The State of California considers the Sierra Nevada mountain yellow-legged frog an 'at risk' species, but it is not State listed as a threatened or endangered species and thus is not protected under the California Endangered Species Act.

California Sport Fishing Regulations include the mountain yellow-legged frog as a protected species that may not be taken or possessed at any time with a sport fishing license. Possession or take of the mountain yellow-legged frog is authorized under special permit from the CDFG. This gives the frog some legal protection from collecting, but does not protect it from other causes of mortality or alterations to its habitat.

The California Forest Practice rules set guidelines for the design of timber harvests on private land to reduce impacts on non-listed species. These rules have little application to the protection of the mountain yellow-legged frog because the vast majority of the species' range is on Federal land, and much of its range is too high in elevation to overlap with lands used for commercial timber harvest.

The California Department of Pesticide Regulation (CDPR) has authority to restrict the use of pesticides. The CDPR Toxic Air Contaminant (TAC) Program includes assessment of the risks posed by airborne pesticides; this assessment involves collection of air samples near sites of pesticide application and in communities near those sites. If air samples indicate that reductions in exposure are needed, mitigation measures are developed to bring about those reductions. However, the TAC program is intended primarily to protect human health, and air samples are not taken at far distant locations from application sites, like those inhabited by the mountain yellow-legged frog in the Sierra Nevada.

The California Environmental Quality Act (CEQA) pertains to projects on non-Federal lands and requires review of any project that is undertaken, funded, or permitted by a State or local governmental agency. If a project with potential impacts on the mountain yellow-legged frog in the Sierra Nevada is reviewed, CDFG personnel could determine that, although not state-listed, the frog is *de facto* an endangered, threatened, or rare species under section 15380 of CEQA. Once significant effects are identified, the lead agency has the option of requiring mitigation for effects through changes in the project or to decide that overriding considerations make mitigation infeasible (CEQA Sec. 21002). In the latter case, projects may be approved that cause significant environmental damage, such as destruction of state-listed endangered species or their habitat. Protection of listed species through CEQA is, therefore, dependent on the discretion of the agency involved. In addition, fish stocking is not subject to disclosure of its potential environmental impacts because it is exempt from CEQA under Article 19 section 15301(j). Therefore, the effects of fish stocking on the mountain yellow-legged frog are not analyzed pursuant to CEQA. Also, the vast majority of the species' range is on Federal land and is affected by Federal actions (other than the State-sponsored fish stocking) that are not subject to CEQA analysis.

Section 1603(a) of the California Fish and Game Code requires a permit from the CDFG for any activity that may alter the bed, channel, or bank of any river, stream, or lake. The permit may incorporate measures to minimize adverse impacts to fish and wildlife. Therefore, this regulation may offer some protection of mountain yellow-legged frog habitat. The extent to which this regulation has provided the mountain yellow-legged frog with protection is unknown because much of the range of this species is on federal lands where few habitat modifications subject to this permit are proposed.

The CDFG is practicing an informal policy on fish stocking in the range of the mountain yellow-legged frog in the Sierra Nevada. This policy directs that: (1) fish will not be stocked in lakes with known populations of mountain yellow-legged frogs, nor in lakes which have not yet been surveyed for mountain yellow-legged frog presence; (2) waters will be stocked only with a fisheries management justification; and (3) the number of stocked lakes will be reduced over time. In 2001, the number of lakes stocked with fish within the range of the mountain yellow-legged frog in the Sierra Nevada was reduced by 75 percent (Milliron 2002a, pp. 6–7; Pert 2002, pers. com.; Pert *et al.* 2002, pers. com.). Water bodies within the same basin and 2 km (1.25 mi) from a known mountain yellow-legged frog population will not be stocked with fish unless stocking is justified through a management plan that considers all the aquatic resources in the basin, or unless there is heavy angler use and no opportunity to improve the mountain yellow-legged frog habitat (Milliron 2002a, p. 5). This policy has not been finalized in writing (Pert *et al.* 2002, pers. com.).

The CDFG is in the process of developing management plans for basins within the range of the mountain yellow-legged frog in the Sierra Nevada (CDFG 2001, p. 1; Milliron 2002a, p. 5; Pert 2002, pers. com.; Pert *et al.* 2002, pers. com.). For example, a plan has been developed, signed, and initiated for the Big Pine Creek wilderness basin in the Inyo National Forest's John Muir Wilderness (CDFG 2001, pp. 1–44), and a similar plan is proposed for the Gable Lakes

basin, also in the John Muir Wilderness area of the Inyo National Forest (Miller 2001, pp. 2–3). The objectives of the Big Pine Creek wilderness basin plan specific to the mountain yellow-legged frog include management in a manner that maintains or restores native biodiversity and habitat quality, supports viable populations of native species, and provides for recreational opportunities that consider historic use patterns (CDFG 2001, p. 3). Under this plan, some lakes are managed primarily for the mountain yellow-legged frog, with few or no angling opportunities, while lakes with high demand for recreational angling are managed primarily for that purpose (CDFG 2001, p. 3). Preliminary results indicate that where the plans are being implemented, the management objective to restore mountain yellow-legged frog habitat is being achieved, and in some areas, mountain yellow-legged frog populations have responded positively (Milliron 2002b, pers. com.). We anticipate that the development and implementation of these basin management plans will be effective in reversing some of the negative impacts of introduced trout on mountain yellow-legged frog populations within a limited geographic area of the affected basins, providing that connectivity is restored between and within metapopulations.

### *Local*

We are not aware of any specific county or city ordinances that provide protection for the Sierra Nevada population of mountain yellow-legged frogs.

*E. Other natural or manmade factors affecting its continued existence.* Several other natural or anthropogenically influenced factors, including contaminants, acid precipitation, climate change and drought, and ambient ultraviolet radiation, have been implicated as contributing to amphibian declines (Corn 1994, pp. 62–63; Alford and Richards 1999, pp. 2–7). These factors have been studied to varying degrees specific to the mountain yellow-legged frog. These factors are discussed below.

The following factors make the mountain yellow-legged frog, along with other amphibians, sensitive to environmental change or degradation: its aquatic and terrestrial phases; its highly permeable skin which is exposed to substances in the water, air, and terrestrial substrate; and the position at which it feeds on the food web, depending on its life stage (Blaustein and Wake 1990, p. 203, 1995, p. 52; Bradford and Gordon 1992, p. 9; Stebbins and Cohen 1995, pp. 227–228). Environmental contaminants have been suggested, and in some cases documented, to negatively affect amphibians by causing the following: direct mortality (Hall and Henry 1992, pp. 66–67; Berrill *et al.* 1994, p. 663, 1995, pp. 1016–1018; Carey and Bryant 1995, p. 16; Relyea and Mills 2001, p. 2493); immune system suppression, which makes amphibians more vulnerable to disease (Carey 1993, pp. 358–360; Carey and Bryant 1995, p. 15; Carey *et al.* 1999, p. 9; Daszak *et al.* 1999, p. 741; Taylor *et al.* 1999, p. 540); disruption of breeding behavior and physiology (Berrill *et al.* 1994, p. 663; Carey and Bryant 1995, p. 16, Hayes *et al.* 2002, p. 5479); disruption of growth or development (Hall and Henry 1992, p. 66; Berrill *et al.* 1993, p. 537, 1994, p. 663, 1995, pp. 1016–1018, 1998, pp. 1741–1744; Carey and Bryant 1995, p. 8; Sparling *et al.* 2001, p. 1595); and disruption of the ability to avoid predation (Hall and Henry 1992, p. 66; Berrill *et al.* 1993, p. 537, 1994, p. 663, 1995, p. 1017, 1998, p.

1744; Carey and Bryant 1995, pp. 8–9; Relyea and Mills 2001, p. 2493; Sparling *et al.* 2001, p. 1595).

Wind-borne pesticides and the compounds that carry pesticides from upwind agriculture that are deposited in the Sierra Nevada have been suggested as a cause of measured sublethal effects to amphibians (Cory *et al.* 1971, p. 3; Davidson *et al.* 2001, pp. 474–475; Sparling *et al.* 2001, p. 1591). In 1998, more than 97 million kilograms (215 million pounds) of pesticides reported to be used in California (CDPR 1998, p. ix). Originating from the agriculture in California's Central Valley, and mainly from the San Joaquin Valley where agricultural activity is greatest, pesticides are passively transported eastward to the high Sierra Nevada where they have been detected in precipitation (rain and snow), air, dry deposition, surface water, plants, fish, and amphibians, including Pacific tree frogs and mountain yellow-legged frogs (Cory *et al.* 1970, p. 204; Zabik and Seiber 1993, p. 80; Aston and Seiber 1997, p. 1488; Datta *et al.* 1998, p. 829; McConnell *et al.* 1998, pp. 1910–1911; LeNoir *et al.* 1999, p. 2721; Sparling *et al.* 2001, p. 1591; Angermann *et al.* 2002, p. 2213). Angermann *et al.* (2002, p. 2213) detected elevated contaminant (polychlorinated biphenyls and toxaphene) levels in Pacific tree frog larvae within the range of the mountain yellow-legged frog, and suggested that these contaminants originate in California's Central Valley and metropolitan areas. Spatial analysis of populations of the California red-legged frog (*Rana aurora draytonii*), foothill yellow-legged frog, Cascades frog (*R. cascadae*), and the mountain yellow-legged frog in the Sierra Nevada showed a strong, statistically significant pattern of population decline associated with greater amounts of upwind agriculture (Davidson *et al.* 2002, pp. 1597–1598). Analysis of upwind pesticide use determined that pesticides may play a large role in the decline of the mountain yellow-legged frog in pristine regions of the Sierra Nevada (Davidson and Knapp 2007, pp. 593–594).

Cholinesterase is an enzyme that functions in the nervous system and is disrupted by organophosphorus pesticides, including malathion, chlorpyrifos, and diazinon (Sparling *et al.* 2001, p. 1591). Reduced cholinesterase activity and pesticide residues have been found in Pacific treefrog larvae collected in the Sierra Nevada downwind of the Central Valley (Sparling *et al.* 2001, p. 1595). Cholinesterase activity was significantly lower in samples from the Sierra Nevada than in samples taken from coastal California, upwind of the Central Valley. No samples were taken above approximately 1,500 m (4,900 ft) elevation (Sparling *et al.* 2001, p. 1592), so in this study there is limited overlap with the 1,074 to 3,650 m (3,525 to 12,000 ft) elevational range (Stebbins 2003, p. 233) of mountain yellow-legged frogs. Although pesticide detections decrease with altitudinal gain, they have been detected at elevations in excess of 3,200 m (10,500 ft) (Zabik and Seiber 1993, p. 88; McConnell *et al.* 1998, p. 1908; LeNoir *et al.* 1999, p. 2721; Angermann *et al.* 2002, pp. 2210–2211). In addition to interfering with nerve function, contaminants such as industrial and agricultural chemicals may act as estrogen mimics (Jobling *et al.* 1996, p. 194), causing abnormalities in reproduction and disrupting endocrine functions (Carey and Bryant 1995, p. 16; Jobling *et al.* 1996, pp. 198–200; Hayes *et al.* 2002, p. 5479), thereby having a negative effect on amphibian populations, including the mountain yellow-legged frog.

In the late 1960s, dichlorodiphenyltrichloroethane (DDT) and its residues were detected in significant quantities in mountain yellow-legged frogs and foothill yellow-legged frogs throughout the Sierra Nevada up to an elevation of 3,660 m (12,000 ft) (Cory *et al.* 1970, p. 210). The origin of this DDT is primarily attributed to agriculture in the Central Valley (Cory *et al.* 1970, p. 205). DDT residues likely from agriculture in the Central Valley still appeared in Pacific treefrog larvae collected in the Sierra Nevada in the late 1990s (Sparling *et al.* 2001, p. 1594), more than 25 years after the use of DDT was banned in the United States. Levels of this toxicant in the mountain yellow-legged frog and foothill yellow-legged frog were significantly higher in the central Sierra Nevada, from the Tuolumne Meadows area of Yosemite National Park, north to Sonora Pass in the Stanislaus National Forest. The origin of DDT at these locations is attributed to two massive applications administered directly to this national forest and national park for pest control (Cory *et al.* 1970, p. 207, 1971, p. 3).

Snow core samples from the Sierra Nevada contain a variety of contaminants from industrial and automotive sources, including hydrogen ions that are indicative of acidic precipitation, nitrogen and sulfur compounds (NH<sub>4</sub>, NO<sub>3</sub>, SO<sub>2</sub>, and SO<sub>4</sub>), and heavy metals (lead, iron, manganese, copper, and cadmium) (Laird *et al.* 1986, p. 275). The pattern of recent frog extinctions in the southern Sierra Nevada corresponds with the pattern of highest concentration of air pollutants from automotive exhaust, possibly due to increases in nitrification (or other changes), caused by those pollutants (Jennings 1996, p. 940). The effects of contaminants on amphibians need further research (Hall and Henry 1992, p. 66). However, the correlative evidence between areas of pesticide contamination in the Sierra Nevada and areas of amphibian decline, along with evidence of an adverse physiological effect from pesticides on amphibians in the Sierra Nevada, indicates that contaminants may present a risk to the mountain yellow-legged frog and may have contributed to the species' decline (Jennings 1996, p. 940; Sparling *et al.* 2001, p. 1591; (Davidson *et al.*, 2002, p. 1599). A small scale research effort at Powell Lake in Stanislaus National Forest deployed semi-permeable membrane devices (SPMDs) to sample for contaminants in this aquatic habitat. Lab analyses of these devices found no assayed chemicals above their detection thresholds (Holdeman 2005, pers. com.).

It has been suggested that contamination from wind-borne pesticides originating from upwind agriculture, and other contaminants originating from metropolitan areas, may compromise amphibian immune systems (Carey 1993, p. 359; Carey *et al.* 1999, p. 7; Angermann *et al.* 2002, p. 2214). An effort to test the hypothesis that contaminants originating in the San Joaquin Valley are suppressing the mountain yellow-legged frog's immune system, thereby making it more vulnerable to disease, is underway (Briggs *et al.* 2002, p. 42).

Laboratory studies have documented sublethal effects on mountain yellow-legged frog embryos at pH 5.25 (pH represents acidity on a negative scale, with 7 being neutral and lower numbers indicating increased acidity). Survivorship of mountain yellow-legged frog embryos and tadpoles was negatively affected as acidity increased (at approximately pH 4.5 or lower), with embryos being more sensitive to increased acidity than tadpoles (Bradford and Gordon 1992, p. 3; Bradford *et al.* 1992, pp. 374–375). Acidic deposition has been suggested as contributing to amphibian declines in the western United States (Blaustein and Wake 1990, p.



204; Carey 1993, p. 357; Alford and Richards 1999, pp. 4–5). Other studies, however, do not support this hypothesis as a contributing factor to amphibian population declines in this area (Bradford and Gordon 1992, pp. 74–77; Bradford *et al.* 1992, p. 375; Corn and Vertucci 1992, p. 366; Corn 1994, p. 61; Bradford *et al.* 1994a, p. 326, 1994b, p. 160).

Acid precipitation has been postulated as a cause of amphibian declines at high elevations in the Sierra Nevada (Bradford *et al.* 1994b, p. 156), because waters there are low in acid neutralizing capacity, and, therefore, are susceptible to changes in water chemistry caused by acidic deposition (Byron *et al.* 1991, p. 271). Near Lake Tahoe, at an elevation of approximately 2,100 m (6,900 ft), precipitation acidity has been documented to have increased significantly (Byron *et al.* 1991, p. 272). In surface waters of the Sierra Nevada, acidity increases and acid neutralizing capacities decrease during snow melt and summer storms, though rarely does pH drop below 5.4 (Nikolaidis *et al.* 1991, p. 339; Bradford and Gordon 1992, p. 73; Bradford *et al.* 1998, p. 2489). The mountain yellow-legged frog breeds shortly after snow melt, thereby exposing its early life stages, which are most sensitive to acidification, to these conditions (Bradford and Gordon 1992, p. 9). However, the hypothesis of acidic deposition as a cause of mountain yellow-legged frog declines has been rejected by field experiments that failed to show differences in water chemistry parameters between occupied and unoccupied mountain yellow-legged frog sites (Bradford *et al.* 1994b, p. 160).

Extreme pH in surface waters of the Sierra Nevada is estimated at 5.0, with most high elevation lakes having a pH of greater than 6 (Bradford *et al.* 1992, p. 374, 1998). Bradford *et al.* (1998, p. 2482) found mountain yellow-legged frog tadpoles to be sensitive to naturally acidic conditions, and that their distribution was significantly related to lake acidity; they were not found in lakes with a pH less than 6. By contrast, the distribution of adult mountain yellow-legged frogs was not significantly related to natural lake acidity or other chemical or physical parameters. Though acidity may have an influence on mountain yellow-legged frog abundance or distribution, it is unlikely to have contributed to this species' decline, given the rarity of lakes acidified either by natural or anthropogenic sources (Bradford *et al.* 1998, pp. 2488–2489).

The last century has included some of the most variable climate reversals documented, at both the annual (extremes and high frequency of El Niño (associated with severe winters) and La Niña (associated with milder winters) events) and near-decadal scales (periods of 5 to 8 year drought and wet periods) (USDA 2001b, p. 33). These events may have negative effects on Sierra Nevada mountain yellow-legged frogs. Severe winters (El Niño) would force longer hibernation times and could stress mountain yellow-legged frogs by reducing the time available for them to feed and breed. Alternately, during mild winters (La Niña), precipitation is reduced. This reduction in precipitation could reduce available breeding habitat and lead to stranding and death of frog eggs and tadpoles. It could also lead to increased exposure to predatory fish by forcing frogs into fish-containing waters if fishless waters dry out.

In California, prolonged droughts are a regular occurrence to which native amphibians have adapted; even severe droughts are not expected to result in widespread population declines (Drost and Fellers 1996, p. 423). However, an increase in the frequency, magnitude, and

duration of droughts caused by global warming may have compounding effects with respect to populations of mountain yellow-legged frogs already in decline. In situations where other factors have resulted in the isolation of mountain yellow-legged frogs to marginal habitats, localized mountain yellow-legged frog population crashes or extirpations due to droughts may exacerbate their isolation and preclude their recolonization or immigration from other populations (Bradford *et al.* 1993, p. 887; Drost and Fellers 1996, p. 424).

Changes in climate that occur faster than the ability of endangered species to adapt could cause local extinctions (U. S. Environmental Protection Agency (EPA) 1989, p. 145). Analysis of the Antarctic Vostok ice core has shown that over the past 160,000 years, temperatures have varied with fluctuations in the concentrations of greenhouse gasses such as carbon dioxide and methane. Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30 percent, methane concentrations have more than doubled, and nitrous oxide (another greenhouse gas) levels have risen approximately 15 percent. The burning of fossil fuels is the primary source of these increases. Global mean surface temperatures have increased 0.3-0.7 °C (0.6-1.2 °F) since the late 19th century (EPA 1997, p. 1). Climate modeling indicates that the overall effects of global warming on California will include higher average temperatures in all seasons, higher total annual precipitation, and decreased spring and summer runoff due to decreases in snowpacks (EPA 1989, p. xxvii, 1997, pp. 246–260). Decreases in spring and summer runoff could lead to the loss of breeding habitat for mountain yellow-legged frogs and increases in instances of stranding mortality of eggs and tadpoles.

Changes in temperature may also affect virulence of pathogens to a different degree than the amphibian immune systems are able to respond (Carey 1993, p. 359) and may make mountain yellow-legged frogs more susceptible to disease. Climate change could also affect the distribution of pathogens and their vectors, exposing mountain yellow-legged frogs (potentially with weakened immune systems as a result of other environmental stressors) to new pathogens (Blaustein *et al.* 2001, p. 1808). An experimental increase in stream water temperature was shown to decrease density and biomass in invertebrates (Hogg and Williams 1996, p. 401); thus, global climate change might have a negative impact on the mountain yellow-legged frog prey base.

Ambient ultraviolet-b (UV-B) radiation (280-320 nanometers (11.0-12.6 microinches)) has increased at north temperate latitudes in the past two decades (Adams *et al.* 2001, p. 521). If UV-B radiation is contributing to amphibian population declines, the declines would likely be greater at higher elevations and at more southerly latitudes where UV-B exposure is greatest, where the thinner atmosphere allows greater penetration of UV-B (Davidson *et al.* 2001, p. 474; Davidson *et al.* 2002, p. 1589). In California, where there is a north-to-south gradient of increasing UV-B exposure, amphibian declines would also likely be more prevalent at southerly latitudes (Davidson *et al.* 2001, p. 474; Davidson *et al.* 2002, p. 1589). Melanic pigment on the upper surfaces of amphibian eggs and larvae protects these sensitive life stages against UV-B damage, an important protection for normal development of amphibians exposed to sunlight, especially at high elevations in clear and shallow waters (Perotti and Diéguez 2006, p. 2064). Blaustein *et al.* (1994c, p. 1793) observed decreased hatching success in several species of

amphibian embryos (the mountain yellow-legged frog was not tested) exposed to increased UV-B radiation, indicating that this may be a cause of amphibian declines.

In a spatial test of the hypothesis that UV-B has contributed to decline of the mountain yellow-legged frog in the Sierra Nevada, Davidson *et al.* (2002, p. 1598) concluded that patterns of this species decline are inconsistent with the predictions of where UV-B related population declines would occur. Greater numbers of extant populations of this species were present at higher elevations than at lower elevations, and population decline was greater in the northern portion of the range of this species than it was in the southern portion. Adams *et al.* (2005, p. 497) also found no evidence that the distribution of mountain-yellow legged frogs in lakes in Sequoia and Kings Canyon National Parks was determined by UV-B. Though it does not appear that UV-B is a factor in the decline of the mountain yellow-legged frog, the absence of the predicted pattern for UV-B-caused decline should not be taken as proof that UV-B is not affecting the mountain yellow-legged frogs, given the potential for one or more factors that cause population declines to mask other factors (Davidson *et al.* 2002, p. 1589).

#### CONSERVATION MEASURES PLANNED OR IMPLEMENTED:

Non-native trout have been partially or completely removed from approximately 20 water bodies in national forests and national parks. In some cases mountain yellow-legged frogs have colonized and established breeding populations in newly fishless water bodies. Efforts to introduce mountain yellow-legged frogs into fishless water bodies in Yosemite National Park have been proposed, however, because nearly all source populations appear to be infected with chytrid fungus this effort is currently on hold (Thompson 2005, pers. com.).

**SUMMARY OF THREATS** (including reasons for addition or removal from candidacy, if appropriate) The mountain yellow-legged frog has two main experimentally verified threats: 1) introduced trout and 2) the pathogenic chytrid fungus, *Batrachochytrium dendrobatidis*. Both of these factors are widespread throughout the range of the mountain yellow-legged frog. Both have also been shown in peer-reviewed scientific studies to have dramatic adverse effects on the mountain yellow-legged frog. Other threats, including degradation of habitat by grazing livestock, disturbance by recreationists, and environmental contaminants, may have some effect on this species, but the immediacy of these threats and the magnitude of their effects is unknown.

For species that are being removed from candidate status:

\_\_\_ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions (PECE)?

**RECOMMENDED CONSERVATION MEASURES:** The mountain yellow-legged frog is not a new candidate species.

## LISTING PRIORITY

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
<b>High</b>	<b>Imminent</b>	Monotypic genus	1
		Species	2
		<b>Subspecies/population</b>	<b>3*</b>
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

### Rationale for listing priority number:

*Magnitude:* The overall magnitude of threats to the Sierra Nevada distinct population segment of the mountain yellow-legged frog is high. Rangewide, the most recent estimates suggest that it has disappeared from more than 90 percent of historically occupied sites and repeated surveys over the past ten years indicate that the decline is continuing, with frogs detectable at fewer and fewer sites over time. Direct predation by nonnative fishes on mountain yellow-legged frogs has resulted in range-wide population declines and local extirpations. Furthermore, the result of these extirpations and the widespread distribution of nonnative trout is that the remaining suitable habitats are fragmented and isolated. Due to habitat fragmentation and population isolation, suitable but unoccupied sites are less likely to get colonized, thus the potential for recovery is reduced. In addition to the clear threat that introduced trout pose, recent peer-reviewed studies and surveys indicate that chytrid fungus is widespread and has resulted in dramatic dieoffs of mountain yellow-legged frogs in fishless habitats. In Sequoia and Kings Canyon National Parks, 19 percent of populations assayed annually were infected with chytrid fungus, and chytrid spread to 16 percent of uninfected populations in one year. In these same parks, where fish have not been stocked since the late 1970s, 2005 surveys found mountain yellow-legged frogs were not detectable in 47 percent of water bodies where they occurred just 3-8 years earlier. In 2005 mountain yellow-legged frogs were undetectable in 37 percent of Yosemite National Park waters where they had been detected 3-5 years earlier; 91 percent of populations assayed were infected with the chytrid fungus.

*Imminence:* The overall immediacy of these threats to the Sierra Nevada distinct population segment of the mountain yellow-legged frog is imminent. The rate of extinction observed over the past decade suggests that extinction could result within a few decades (assuming that the rate of extinction and recolonization observed over this time period accurately reflects the long-term rates). While nonnative trout severely limit the habitat available to this species, recent declines appear to be caused by a disease, specifically chytrid fungus. Where extensive research has been conducted this disease has been found to be widely distributed and spreading. Research has shown that the disease can be transmitted among tadpoles and between tadpoles and adults, and that infected tadpoles rarely survive beyond metamorphosis. Infected populations in the wild have been observed to decline and commonly go locally extinct following infection by the chytrid fungus. Therefore, we conclude that all remaining mountain yellow-legged frog populations within the Sierra Nevada are at substantial risk of decline or extirpation as a result of infection by this pathogen. Also, due to the widespread distribution of nonnative trout a large proportion of potential breeding habitat remains unsuitable, and these waters additionally impede movement and isolate remaining populations.

Rationale for Change in Listing Priority Number (insert if appropriate)

X Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

Is Emergency Listing Warranted? After reviewing the current status and distribution of the mountain yellow-legged frog and the threats associated with the species, we have determined that an emergency listing of the species is not warranted at this time. Numerous stable and intact metapopulations of mountain yellow-legged frog occur throughout its current range. Efforts to remove introduced fish from lakes containing the species have shown to improve the local status of the mountain yellow-legged frog. The Forest Service and National Park Service managing the areas where mountain yellow-legged frog occur are continuing to monitor the species, as well as continuing efforts to remove introduced fish species from mountain yellow-legged frog habitats. The purpose of the emergency rule provision of the Act is to prevent species from becoming extinct by affording them immediate protection while the normal rule making procedures are being followed. Although the Sierra Nevada mountain yellow-legged frog has declined and apparently continues to decline (the species has been detected at less than 10 percent of historic sites), the species would not benefit from the special protections afforded by emergency listing. This is because the two main documented threats, 1) the presence of nonnative fishes throughout the frog's historically fishless high elevation habitats and 2) the pathogenic chytrid fungus, would not be impeded or reduced by emergency listing. However, due to the magnitude of observed trends and continuing threats, listing through the routine process is overdue, and should proceed in as timely a fashion as is possible should on-going conservation measures for the frog be delayed or curtailed. We will continue to work with the scientific community and the other Federal and State Resource Agencies in developing and implementing effective conservation measures for the species.

**DESCRIPTION OF MONITORING:** The Service regularly seeks the most current information available from Federal, State, and independent biologists working within the range of the Sierra Nevada mountain yellow-legged frog. Monitoring of the Sierra Nevada mountain yellow-legged frog includes reviewing the current scientific literature, and contacting species experts and state and federal agencies regarding the species status and threats. We are currently working with the U.S. Forest Service on a Conservation Assessment and Strategy as required by the Sierra Nevada Forest Plan Amendment of 2004.

#### **COORDINATION WITH STATES**

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment: California

Indicate which State(s) did not provide any information or comments: Nevada (within the historic but not the current range of the species, so the Service did not request information)

#### **LITERATURE CITED**

- Adams, M.J., D.E. Schindler, and R.B. Bury. 2001. Association of amphibians with attenuation of ultraviolet-b radiation in montane ponds. *Oecologia*. 128:519–525.
- Adams, M.J., B.R. Hossack, R.A. Knapp, P.S. Corn, S.A. Diamond, P.C. Trenham, and D.B. Fagre. 2005. Distribution patterns of lentic-breeding amphibians in relation to ultraviolet radiation exposure in western North America. *Ecosystems*. (8):488–500.
- Alford R.A., and S.J. Richards. 1999. Global amphibian declines: a problem in applied ecology. *Annual review of Ecology and Systematics*. 30:133–165.
- Anderson, S. 2002. (USFS, Sequoia National Forest). August 5, 2002, and August 9, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- Angermann, J.E., G.M. Fellers, and F. Matsumura. 2002. Polychlorinated biphenyls and toxaphene in pacific tree frog tadpoles (*Hyla regilla*) from the California Sierra Nevada, USA. *Environmental Toxicology and Chemistry*. 21(10):2209–2215.
- Armour, C.A., D. Duff, and W. Elmore. 1994. The effects of livestock grazing on western riparian and stream ecosystems. *Fisheries*. 19:9–12.
- Aston, L.S. and J.N. Seiber. 1997. Fate of summertime organophosphate pesticide residues in the Sierra Nevada Mountains. *Journal of Environmental Quality*. 26:1483–1492.
- Bahls, P. 1992. The status of fish populations and management of high mountain lakes in the western United States. *Northwest Science*. 66(3):183–193.

- Beesley, D. 1996. Reconstructing the landscape: an environmental history, 1820-1960. In: Sierra Nevada ecosystem project, final report to congress. Volume II, Chapter 1. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Berrill, M., S. Bertram, A. Wilson, S. Louis, D. Brigham, and C. Stromberg. 1993. Lethal and sublethal impacts of pyrethroid insecticides on amphibian embryos and tadpoles. *Environmental Toxicology and Chemistry*. 12:525–539.
- Berrill, M., S. Bertram, L. McGillivray, M. Kolohon, and B. Pauli. 1994. Effects of low concentrations of forest-use pesticides on frog embryos and tadpoles. *Environmental Toxicology and Chemistry*. 13(4):657–664.
- Berrill, M., S. Bertram, B. Pauli, D. Coulson, M. Kolohon, and D. Ostrander. 1995. Comparative sensitivity of amphibian tadpoles to single and pulsed exposures of the forest-use insecticide fenitrothion. *Environmental Toxicology and Chemistry*. 14(6):1011–1018.
- Berrill, M., D. Coulson, L. McGillivray, and B. Pauli. 1998. Toxicity of endosulfan to aquatic stages of anuran amphibians. *Environmental Toxicology and Chemistry*. 17(9):1738–1744.
- Blaustein, A.R., and D.B. Wake. 1990. Declining amphibian populations: a global phenomenon? *Trends in Ecology and Evolution*. 5(7):203–204
- Blaustein, A.R., and D.B. Wake. 1995. The puzzle of declining amphibian populations. *Scientific American*. 272:52–57.
- Blaustein, A.R., D.B. Wake, and W.P. Sousa. 1994a. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology*. 8(1):60–71
- Blaustein, A.R., D.G. Hokit, R.K. O'Hara, and R.A. Holt. 1994b. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. *Biological Conservation*. 67:251–254.
- Blaustein, A.R., P.D. Hoffman, D.G. Hokit, J.M. Kiesecker, S.C. Walls, and J.B. Hays. 1994c. UV repair resistance to solar UV-B in amphibian eggs: a link to population declines? *Proceedings of the National Academy of Science*. 91:1791–1795.
- Blaustein A.R., L.K. Belden, D.H. Olson, D.M. Green, T.L. Root, and J.M. Kiesecker. 2001. Amphibian breeding and climate change. *Conservation Biology*. 15(6):1804–1809.
- Bohn, C.C., and J.C. Buckhouse. 1985. Some responses of riparian soils to grazing management in northeastern Oregon. *Journal of Range Management*. 38(4):378–381.

- Boiano, D. 2009. (NPS, Sequoia and Kings Canyon National Parks). April 15, 2009, telephone conversation with Karuzas, J. (U.S. Fish and Wildlife Service).
- Bradford, D.F. 1983. Winterkill, oxygen relations, and energy metabolism of a submerged dormant amphibian, *Rana muscosa*. *Ecology* 64:1171–1183.
- Bradford, D. F. 1984. Temperature modulation in a high elevation amphibian, *Rana muscosa*. *Copeia*, 1984(4):966–976.
- Bradford, D.F. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implications of the negative effect of fish introductions. *Copeia* 1989:775–778.
- Bradford, D. F. 1991. Mass mortality and extinction in a high elevation population of *Rana muscosa*. *Journal of Herpetology*, 25(2):174–177.
- Bradford, D.F. and M.S. Gordon, 1992. Aquatic amphibians in the Sierra Nevada; current status and potential effects of acidic deposition on populations. Final report to the California Air Resources Board. Contract Number A932–139. 87 Pps. plus appendices.
- Bradford, D.F, C. Swanson, and M.S. Gordon. 1992. Effects of low pH and aluminum on two declining species of amphibians in the Sierra Nevada, California. *Journal of Herpetology*. 26:369–377.
- Bradford, D. F., F. Tabatabai, and D. M. Graber. 1993. Isolation of remaining populations of the native frog, *Rana muscosa*, by introduced fishes in Sequoia and Kings Canyon National Parks, California. *Conservation Biology* 7(4):882–888.
- Bradford, D.F., D.M. Graber, and F. Tabatabai. 1994a. Population declines of the native frog, *Rana muscosa*, in Sequoia and Kings Canyon National Parks, California. *The Southwestern Naturalist* 39:322–327.
- Bradford, D.F., M.S. Gordon, D.F. Johnson, and R.D. Andrews. 1994b. Acidic deposition as an unlikely cause for amphibian population declines in the Sierra Nevada, California. *Biological Conservation* 69:155–161.
- Bradford, D. F., S. D. Cooper, T. M. Jenkins, Jr., K. Kratz, O. Sarnelle, and A. D. Brown. 1998. Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. *Canadian Journal of Aquatic Sciences*, 55:2478–2491.
- Briggs C.J., J. Taylor, C. Moritz, and R.A. Knapp. 2002. Amphibian disease dynamics in a fragmented landscape. Proposal to the National Institute of Health, Ecology of Infectious Disease Program. Submitted by the Regents of the University of California. University of California, Berkeley, California. Funded June 2002.



- Brown, C. 2005. (USFS Pacific Southwest Research Station). November 11, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Byron, E., R. Axler, and C. Goldman. 1991. Increased precipitation acidity in the Central Sierra Nevada. *Atmospheric Environment* 25A(2): 271–275.
- California Department of Fish and Game. 2001. Aquatic biodiversity management plan for the Big Pine Creek wilderness basin of the Sierra Nevada, Inyo County, California, 1999–2005. Prepared by Milliron, C, approved by Pickard, A. Fleming, G. and Morey, S. California Department of Fish and Game, Eastern Sierra and Inland Deserts Region, Region 6, Bishop, California.
- California Department of Pesticide Regulation. 1998. Pesticide Use Report: 1998. Department of Pesticide Regulation, Sacramento, California.
- Camp, C.L. 1917. Notes on the systematic status of the toads and frogs of California. *University of California Publications in Zoology*. 17(9):115–125.
- Carey, C. 1993. Hypothesis concerning the causes of the disappearance of boreal toads from the mountain of Colorado. *Conservation Biology* 7: 355–361.
- Carey, C. and C.J. Bryant. 1995. Possible interrelationships among environmental toxicants, amphibian development, and decline of amphibian populations. *Environmental Health Perspectives*. 103: Supplement 4:13–17.
- Carey, C., N. Cohen, and L. Rollins-Smith. 1999. Amphibian declines: and immunological perspective. *Developmental and Comparative Immunology*. 1999:1–14.
- Carlson, A. 2002a. (USFS, Tahoe National Forest). August 29, 2002, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Carlson, A. 2002b. (USFS, Tahoe National Forest). August 7, 2002, telephone conversation with Epanchin, P. (U.S. Fish and Wildlife Service).
- Case, S. M. 1978. Electrophoretic variation in two species of ranid frogs, *Rana boylei* and *R. muscosa*. *Copeia*, 1978(2):311–320.
- Chaney, E., W. Elmore, and W.S. Platts. 1990. Livestock grazing on western riparian areas. U.S. Environmental Protection Agency and the Northwest Resource Information Center. Eagle, Idaho. 45 Pp.
- Clary, W.P. and J.W. Kinney. 2000. Streambank response to simulated grazing. USDA Forest Service Proceedings RMRS-P-13.

- Cole D.N., and P.B. Landres. 1996. Threats to wilderness ecosystems: impacts and research needs. *Ecological Applications*. 6(1):168–184.
- Colwell M.A., K.S. Beatty. 1995. Bird communities and frogs at Yosemite's high lakes. Final report submitted to Yosemite Association. Wildlife Department, California State University, Humboldt. Humboldt, California.
- Conway, L. 2002. (USFS, Stanislaus National Forest). August 1, 2002, telephone conversation with Epanchin, P. (U.S. Fish and Wildlife Service).
- Corn, P.S. and F.A. Vertucci. 1992. Descriptive risk assessment of the effects of acidic deposition on rocky mountain amphibians. *Journal of Herpetology*. 26(4):361–369.
- Corn, P.S. 1994. What we know and don't know about amphibian declines in the west. Pp. 59–67, *in* Sustainable ecological systems: implementing an ecological approach to land management. Covington, W.W. and L.F. DeBano (technical coordinators). USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado. General Technical Report RM-247.
- Cory, L. 1962a. Patterns of geographic variation in Sierra Nevada ranids (abstract). *American Zoologist*. 2:401.
- Cory, L. 1962b. Life history and behavior differences between ranids in isolated populations in the Sierra Nevada (abstract). *American Zoologist*. 2:515.
- Cory, L. 1963. Effects of introduced trout on the evolution of native frogs in the high Sierra Nevada mountains. Vol 2, p. 172. *In*: Proceedings from the XVI International Congress of Zoology. J.A. Moore (ed.). 20–27 August 1963, Washington, D.C. Published by XVI International Congress of Zoology, Washington, D.C.
- Cory, L.C., P. Fjeld, and W. Serat. 1970. Distribution patterns of DDT residues in the Sierra Nevada Mountains. *Pesticides Monitoring Journal*. 4:205-211.
- Cory, L.C., P. Fjeld, and W. Serat. 1971. Environmental DDT and the genetics of natural populations. *Nature*. 229(5280):128-130.
- Crother, B.I., J. Boundy, F.T. Burbrink, J.A. Campbell, K. de Queiroz, D.R. Frost, R. Highton, J. B. Iverson, F.Kraus, R.W. McDiarmid, J.R. Mendelson III, P.A. Meylan, T.W. Reeder, M.E. Seidel, S.G. Tilley, D.B. Wake. 2008. Scientific and standard english names of amphibians and reptiles of North America north of Mexico, with comments regarding confidence in our understanding. Society for the Study of Amphibians and Reptiles. January 2008. 85 pp.

- Daszak, P., L. Berger, A.A. Cunningham, A.D. Hyatt, D.E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. *Emerging Infectious Diseases* 5:735–748.
- Datta, S., L. Hansen, L. McConnell, J. Baker, J. LeNoir, and J.N. Seiber. 1998. Pesticides and PCB contaminants in fish and tadpoles from the Kaweah River Basin, California. *Bulletin of Environmental Contamination and Toxicology*. 60:829–836.
- Davidson, C., R. A. Knapp. 2007. Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs. *Ecological Applications*. 17(2): 587–597.
- Davidson, C., H.B. Shaffer, and M.R. Jennings. 2001. Declines of the California red-legged frog: climate, UV-B, habitat, and pesticides hypotheses. *Ecological Applications*. 11(2):464–479.
- Davidson, C., H.B. Shaffer, and M.R. Jennings. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B and climate change hypotheses for California amphibian declines. *Conservation Biology*. 16(6):1588–1601.
- deMaynadier, P.G. and M.L. Hunter. 2000. Road effects on amphibian movements in a forested landscape. *Natural Areas Journal*. 20:56–65.
- Drost, C. A., and G. M. Fellers. 1994. Decline of frog species in the Yosemite section of the Sierra Nevada. United States Department of the Interior, National Park Service, Cooperative National Park Studies Unit, The University of California at Davis, Technical Report (NPS/WRUC/NRTR 94-02 [UC CPSU TR #56]):iv+56 p.
- Drost C. and G. Fellers, 1996. Collapse of a Regional Frog Fauna in the Yosemite Area of the California Sierra Nevada, USA, *Conservation Biol.* 10:(2) pp. 414–425.
- Easton, M.A. 2002. (USFS, Humboldt Toiyabe National Forest). August 13, 2002 electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Eddinger, H. 2002. (USFS, Sierra National Forest). August 9, 2002, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Erman, N.A. 1996. Status of aquatic invertebrates. In: Sierra Nevada ecosystem project, final report to congress. Volume II, Chapter 35. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Feldman C.R., and J.A. Wilkinson. 2000. *Rana muscosa* (mountain yellow-legged frog), predation. *Herpetological Review*. 31(2):102

- Fellers, G.M. 1994. An Assessment of the Status of Amphibians in the vicinity of California National Parks: 1993 progress report.
- Fellers G.M., D.E. Green, and J.E. Longcore. 2001. Oral chytridiomycosis in the mountain yellow-legged frog (*Rana muscosa*). *Copeia*. 4:945–953
- Fleischner T.L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology*. 8(3):629–644.
- Green, D. M. 1986a. Systematics and evolution of western North American frogs allied to *Rana aurora* and *Rana boylei*: Karyological evidence. *Systematic Zoology*, 35(3):273–282.
- Green, D. M. 1986b. Systematics and evolution of western North American frogs allied to *Rana aurora* and *Rana boylei*: Electrophoretic evidence. *Systematic Zoology*, 35(3):283–296.
- Green, D.M. 1993. (McGill University). June 16, 1993, letter to Jackson, G. (U.S. Fish and Wildlife Service).
- Green, D.E. and C. Kagarise Sherman. 2001. Diagnostic histological findings in Yosemite toads (*Bufo canorus*) from a die-off in the 1970s. *Journal of Herpetology*. 35:92–103.
- Grinnel, J. and T.I. Storer. 1924. Animal life in Yosemite: an account of the mammals, birds, reptiles, and amphibians in a cross-section of the Sierra Nevada. University of California Press. Berkeley, California.
- Hall, R.J. and P.F.P. Henry. 1992. Assessing effects of pesticides on amphibians and reptiles: status and needs. *Herpetological Journal* 2:65–71.
- Hamilton, Steven J., Susan F. McDonald, Mark P. Gaikowski, and Kevin J. Buhl. 1996. Toxicity of fire retardant chemicals to aquatic organisms: progress report. International Wildland Fire Foam Symposium, Thunderbay, Ontario. 132–144pp. Northern Prairie Wildlife Research Center Home Page.  
<http://www.npwrc.usgs.gov/resource/othrdata/fireweb/toxicity/toxicity.htm> (Version 02MAR98).
- Hanski, I. 1997. Metapopulation dynamics: from concepts and observations to predictive models. Pps. 69–91. In: I. A. Hanski and M. E. Gilpin, editors. *Metapopulation biology: ecology, genetics, and evolutions*. Academic Press, San Diego.
- Hanski, I. and D. Simberloff. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. Pps. 5–26. In: I. A. Hanski and M. E. Gilpin, editors. *Metapopulation biology: ecology, genetics, and evolutions*. Academic Press, San Diego.

- Hayes, M.P., and M.R. Jennings. 1986. Decline of Ranid frog species in western North America: are bullfrogs (*Rana catesbeiana*) responsible? *Journal of Herpetology*, 20(4):490–509.
- Hayes, T., K. Haston, M. Tsui, A. Hoang, C. Haeffele, and A. Vonk. 2002. Atrazine-induced hermaphroditism at 0.1 PPB in American leopard frogs (*Rana pipiens*): laboratory and field evidence. *Environmental Health Perspectives, Journal of the National Institute of Environmental Health Sciences*. doi:10.1289/ehp.5932 (available at <http://dx.doi.org/>). 23 October 2002.
- Heller, C. L. 1960. The Sierra yellow-legged frog. *Yosemite Nature Notes*, 39(5):126–128.
- Helms, J. A. and J. C. Tappeiner. 1996. Silviculture in the Sierra. In: Sierra Nevada Ecosystem Project: final report to congress. Vol. II, Chapter 15. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Hillis, D.M., and S.K. Davis. 1986. Evolution of ribosomal DNA: Fifty million years of recorded history in the frog genus *Rana*. *Evolution* 40:1275–1288.
- Hillis, D.M. and T.P. Wilcox. 2005. Pylogeny of the new world true frogs (*Rana*). *Molecular Phylogenetics and Evolution* 34(2005):299–314.
- Hogg, I.D., and D.D. Williams. 1996. Response of stream invertebrates to a global-warming thermal regime: an ecosystem level manipulation. *Ecology*. 77:395–408.
- Holdeman, S. 2005.(USFS, Stanislaus National Forest). October 25, 2005, telephone conversation with U.S. Fish and Wildlife Service.
- Hopkins, T. 2002. (USFS, Plumas National Forest). July 24, 2002, telephone conversation with Epanchin, P. (U.S. Fish and Wildlife Service).
- Jennings, M.R. 1984. *Rana muscosa* (mountain yellow-legged frog). *Herpetological Review*. 15(2):52.
- Jennings, M.R. and M.P. Hayes. 1994. Mountain yellow-legged frog (*Rana muscosa*) Camp 1917. Amphibian and reptile species of special concern in California. Pp. 74–78. California Department of Fish and Game, Inland Fisheries Division. Rancho Cordova, California.
- Jennings, M. R. 1995. Native ranid frogs in California. Pages 131-134 In: E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (editors). *Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals,*

and Ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C. xi+530 p.

Jennings, M.R. 1996. Status of amphibians. In: Sierra Nevada ecosystem project: final report to congress. Volume II, Chapter 31. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.

Jennings, W.B., D.F. Bradford, and D. F. Johnson. 1992. Dependence of the garter snake (*Thamnophis elegans*) on amphibians in the Sierra Nevada of California. *Journal of Herpetology* 26(4):503–505

Jobling, S., D. Sheahan, J.A. Osborne, P. Matthiessen, and J.P. Sumpter. 1996. Inhibition of testicular growth in rainbow trout (*Oncorhynchus mykiss*) exposed to estrogenic alkylphenolic chemicals. *Environmental Toxicology and Chemistry*. 15(2):194–202.

Kauffman, J.B., and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a review. *Journal of Range Management*. 37(5):430–437.

Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Impacts of cattle on streambanks in Northeastern Oregon. *Journal of Range Management*. 683–685.

Kiesecker, J.M., A.R. Blaustein, and C.L. Miller. 2001. Transfer of a pathogen from fish to amphibians. *Conservation Biology* 15:1064–1070.

Knapp, R.A. 1993a. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). June 15, 1993 letter to B. Pritchard, Mono Lake Ranger District, Inyo National Forest, from R.A. Knapp, Sierra Nevada Aquatic Research Laboratory.

Knapp, R.A. 1993b. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). October 22, 1993 letter to B. Pritchard, Mono Lake Ranger District, Inyo National Forest, from R.A. Knapp, Sierra Nevada Aquatic Research Laboratory.

Knapp R.A. 1994a. The high cost of high sierra trout. *Wilderness record*, proceedings of the California wilderness coalition. 19(2):1–3.

Knapp, R.A. 1994b. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). September 28, 1994 letter to R. Keil, Inyo National Forest, from R.A. Knapp, Sierra Nevada Aquatic Research Laboratory.

Knapp R.A. 1996. Nonnative trout in natural lakes of the Sierra Nevada: an analysis of their distribution and impacts on native aquatic biota. In: Sierra Nevada ecosystem project, final report to congress. Volume III, Chapter 8. Assessments and scientific basis for

management options. Center for Water and Wildland Resources, University of California, Davis, California.

- Knapp, R.A. 2002a. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). July 24, 2002, August 4, 2002, August 12, 2002, September 20, 2002, October 31, 2002, and December 16, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- Knapp, R.A. 2002b. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). Recent observations and insights regarding disease, die-offs, and malformations. Presented at: Declining Amphibian Task Force of the World Conservation Union, California/Nevada Working Group meeting, January 10–11, 2002. Notes taken by P. Epanchin. (U.S. Fish and Wildlife Service). San Diego, California.
- Knapp R.A. 2005a. Effects of nonnative fish and habitat characteristics on lentic herpetofauna in Yosemite National Park, USA. *Biological Conservation* 121(2005):265–279.
- Knapp, R.A. 2005b. (Sierra Nevada Aquatic Research Laboratory, University of California). October 25 and November 04, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Knapp, R.A. 2008. (Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara). February 26, 2008, electronic message to Karuzas, J. (U.S. Fish and Wildlife Service).
- Knapp R.A. and R.K. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: impacts and management implications. *North American Journal of Fisheries Management*. 16:805–820.
- Knapp R.A. and R.K. Matthews. 1998. Eradication of nonnative fish by gill netting from a small mountain lake in California. *Restoration Ecology*. 6(2):207–213.
- Knapp R.A. and R.K. Matthews. 2000. Nonnative fish introductions and the decline of the mountain yellow-legged frog from within protected areas. *Conservation Biology*, 14(2):428–438.
- Knapp R.A., R.K. Matthews, and O. Sarnelle. 2001. Resistance and resilience of alpine lake fauna to fish introductions. *Ecological Monographs*. 71(3):401–421.
- Knapp, R. A., D. M. Boianao, V. T. Vredenburg, 2007a. Removal of nonnative fish results in a population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa*). *Biological Conservation*. 135:11–20

- Knapp, R.A., J.A.T. Morgan, P.B. Boyle, D.B. Wake, V. T. Vredenberg, S. Thompson, S.S. Sweet, D. F. Bradford, C. Davidson, H. Welsh, K. Pope and C. Moritz, 2007b. Letter expressing concern over the decline of the mountain yellow-legged frog and its current listing status. February 1, 2007 letter to the U.S. Fish and Wildlife Service.
- Kondolph, G.M., R. Kattelman, M. Embury, and D.C. Erman. 1996. Status of riparian habitat. In: Sierra Nevada ecosystem project, final report to congress. Volume II, Chapter 36. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Laird, L.B., H.E. Taylor, and V.C. Kennedy. 1986. Snow chemistry of the Cascade-Sierra Nevada Mountains. *Environmental Science and Technology* 20:275–290.
- Landres P., S. Meyer, and S. Matthews. 2001. The Wilderness Act and fish stocking: an overview of legislation, judicial interpretation, and agency implementation. *Ecosystems*. 4:287–295.
- Lehtinen, R.M., S.M. Galatowitsch, and J.R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands*. 19:1–12.
- LeNoir, J.S., L.L McConnell, G.M. Fellers, T.M. Cahill, and J.N. Seiber. 1999. Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada mountain range, USA. *Environmental Toxicology and Chemistry*. 18(12):2715–2722.
- Lemly, D.A. 1998. Bacterial growth on stream insects: potential for use in bioassessment. *Journal of the North American Benthological Society*. 17(2):228–238.
- Linsdale, J.M. 1940. Amphibians and reptiles in Nevada. *Proceedings of the American Academy of Arts and Science*. 73(8):197–257.
- Livezey, R.L. and A.H. Wright. 1945. Descriptions of four salientian eggs. *The American Midland Naturalist*. 34:701-706.
- Long, M.L. 1970. Food habits of *Rana muscosa* (Anura: Ranidae). *Herpeton, Journal of the Southwestern Herpetologists Society*. 5(1):1–8.
- Macey, J.R, J.L. Starsburg, J.A. Brisson, V.T. Vredenburg, M. Jennings, and A. Larson. 2001. Molecular phylogenetics of western North American frogs of the *Rana boylei* species group. *Molecular phylogenetics and evolution*. 19(1):131–143.
- Mao, J., D.E. Green, G. Fellers, and V.G. Chinchar. 1999. Molecular characterization of iridoviruses isolated from sympatric amphibians and fish. *Virus Research*. 63:45–52.



- Mark, T. 2005. (USFS, Tahoe National Forest). November 03, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Marlow, C.B. and T.M. Pogacnik. 1985. Time of grazing and cattle-induced damage to streambanks. Paper presented at the North American Riparian Conference. University of Arizona, Tuscon.
- Martin, D.L. 1992. Sierra Nevada anuran survey: An investigation of amphibian population abundance in the National Forests of the Sierra Nevada of California. Summer 1992 survey. Prepared for the U.S. Forest Service. 54 pp.
- Matthews, K. R., and K. L. Pope. 1999. A telemetric study of the movement patterns and habitat use of *Rana muscosa*, mountain yellow-legged frog, in a high-elevation basin in Kings Canyon National Park, California. *Journal of Herpetology*, 33(4):615–624.
- Matthews, K.R., K.L. Pope, H.K. Preisler, and R.K. Knapp. 2001. Effects of nonnative trout on Pacific treefrogs (*Hyla regilla*) in the Sierra Nevada. *Copeia*. 2001:1130–1137.
- McCloud, K. 2002. (U.S. Fish and Wildlife Service, Law Enforcement Division). December, 5, 2002, telephone conversation with Nagano, C. (U.S. Fish and Wildlife Service).
- McConnell, L.L., J.S. LeNoir, S. Datta and J.N. Seiber. 1998. Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA. *Environmental Toxicology and Chemistry*. 10:1908–1916.
- McFarland, M. (USFS, Lassen National Forest). July 29, 2002 and November 4, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- McKelvey, K.S., C.N. Skinner, C. Chang, D.C. Erman, S.J. Husari, D.J. Parsons, J.W. van Wagtendonk, C.P. Weatherspoon. 1996. An overview of fire in the Sierra Nevada. In: Sierra Nevada ecosystem project, final report to congress. Volume II, Chapter 37. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Meehan W.R. and W.S. Platts. 1978. Livestock grazing and the aquatic environment. *Journal of Soil and Water Conservation*. 6:274–278.
- Menke, J.W, C. Davis, and P. Beesley. 1996. Rangeland assessment. In: Sierra Nevada ecosystem project, final report to congress. Volume III, Chapter 22. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Miller, B. (California Department of Fish and Game). November 26, 2001, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).

- Milliron, C. 2002a. (California Department of Fish and Game). July 31, 2002, August 2, 2002, and August 9, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- Milliron, C. 2002b. (California Department of Fish and Game). November 8, 2002, telephone message for Epanchin, P. (U.S. Fish and Wildlife Service).
- Milliron, C. 2005. (California Department of Fish and Game). October 25, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Moyle, P.B. 2002. Inland Fishes of California, revised and expanded. University of California Press.
- Moyle, P.B., R.M. Yoshiyama, R.A. Knapp. 1996. Status of Fish and Fisheries. In: Sierra Nevada ecosystem project, final report to congress. Volume II, Chapter 33. Assessments and scientific basis for management options. Center for Water and Wildland Resources, University of California, Davis, California.
- Mullally, D.P. 1953. Observations on the ecology of the toad *Bufo canorus*. Copeia. 3:182–183.
- Mullally, D.P. 1959. Notes on the Natural History of *Rana muscosa* Camp in the San Bernardino Mountains. Herpetologica. 15:78–80.
- Mullally, D.P., and J.D. Cunningham. 1956. Ecological relations of *Rana muscosa* at high elevations in the Sierra Nevada. Herpetologica. 12:189–198.
- Murphy, L.B. 2002a. (USFS, Humboldt Toiyabe National Forest). December 16, 2002 electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Murphy, L.B. 2002b. (USFS, Humboldt-Toiyabe National Forest). July 31, 2002, telephone conversation with Epanchin, P. (U.S. Fish and Wildlife Service).
- Muskopf, S. 2005. (Lake Tahoe Basin Management Area). October 25, 2005, telephone conversation with U.S. Fish and Wildlife Service.
- Muskopf, S. 2009. (USFS, Lake Tahoe Basin Management Unit). March 30, 2009 electronic message to Karuzas, J. (U.S. Fish and Wildlife Service).
- Muths, E., P.S.Cara, A.P. Pessier and D.E.Green. 2003. Evidence for disease-related amphibian decline in Colorado. Biological Conservation. 110:357–365.

- National Park Service. 2001. Preliminary restoration of mountain yellow-legged frogs, environmental assessment and finding of no significant impact. Department of the Interior, Sequoia and Kings Canyon National Parks, Three Rivers, California.
- Nikolaidis, N.P., V.S. Nikolaidis, J.L. Schnoor. Assessment of episodic acidification in Sierra Nevada, California. *Aquatic Sciences*. 53(4):330–344.
- Panik, H.R. 1995. An ecological Survey of the mountain yellow-legged frog (*Rana muscosa*) in Nevada. Prepared for the Nevada Division of Wildlife, September 1995.
- Panik, R. 2002. (Western Nevada Community College). August 20, 2002, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Parker, D. 1994. Inyo National Forest amphibian status report. USFS, Inyo National Forest. Bishop, California.
- Perotti, M.G., and M.d.C. Diéguez. 2006. Effect of UV-B exposure on eggs and embryos of patagonian anurans and evidence of photoprotection. *Chemosphere* 65 (2006): 2063–2070.
- Pert, E. 2002. (California Department of Fish and Game). California Department of Fish and Game and introduced fishes: California Department of Fish and Game's high mountain lakes surveys and stocking policy. Presented at: Declining Amphibian Task Force of the World Conservation Union, California/Nevada Working Group meeting, January 10-11, 2002. Notes taken by P. Epanchin. (U.S. Fish and Wildlife Service). San Diego, California.
- Pert, E., Eng, L., Milliron, C., Kleinfelter, J., Lehr, S., Bolster, B., Stephens, S., Hanson, J., Roscoe, T., McGriff, D., and Becker, D. (California Department of Fish and Game). April 4, 2002. California Department of Fish and Game meeting with United States Fish and Wildlife Service (Epanchin, P., Martin, J., Douglas, J., and Moore, S. (U.S. Fish and Wildlife Service)). Mountain yellow-legged frog and Yosemite toad data sharing and stocking policy meeting. Notes taken by P. Epanchin. (U.S. Fish and Wildlife Service). California Department of Fish and Game's Sacramento Valley and Central Sierra Regional Office, Region 2, Rancho Cordova, California.
- Pilliod D.S., and C.R. Peterson. 2001. Local and landscape effects of introduced trout on amphibians in historically fishless waters. *Ecosystems*. 4:322–333.
- Pister E.P. 2001. Wilderness fish stocking: history and perspective. *Ecosystems*. 4:279–286.
- Pope, K. 1999a. Mountain yellow-legged frog habitat use and movement patterns in a high elevation basin in Kings Canyon National Park. Unpublished MS Thesis, California State Polytechnic University, San Luis Obispo, California. 64 Pages.

Pope, K. 1999b. *Rana muscosa* (mountain yellow-legged frog): Diet. *Herpetological Review*, 30(3):163–164.

*Public Lands Council et al. v. Babbitt Secretary of the Interior et al.* 2000. Certiorari to the United States Court of Appeals for the Tenth Circuit. Justice Breyer. 167 F. 3d 1287.

Rachowicz, L. J. 2005. (NPS, Yosemite National Park). November 03, 2005 telephone conversation with U.S. Fish and Wildlife Service.

Rachowicz, L.J. and V.T. Vredenburg. 2004. Transmission of *Batrachocytridium dendrobatidis* within and between amphibian life stages. *Diseases of Aquatic Organisms* 61:75–83.

Rachowicz, L.J. J-M Hero, R.A. Alford, J.W. Taylor, J.A.T. Morgan, V.T. Vredenburg, J.P. Collins, and C.J. Briggs. 2005. The novel and endemic pathogen hypotheses: competing explanations for the origin of emerging infectious diseases. *Conservation Biology* 19(5):1441–1448.

Rachowicz, L.J., R.A. Knapp, J.A.T. Morgan, M.J. Stice, V.T. Vredenburg, J.M. Parker, and C.J. Briggs. 2006. Emerging infectious disease as a proximate cause of amphibian mass mortality. *Ecology* 87(7):1671-1683

Reiner, J. 2002. (USFS, Lake Tahoe Basin Management Unit). July 31, 2002 telephone conversation with Epanchin, P. (U.S. Fish and Wildlife Service).

Relyea, R.A. and N.M. Mills. 2001. Predator-induced stress makes the pesticide carbaryl more deadly to gray treefrog tadpoles (*Hyla versicolor*). *Proceedings of the National Academy of Sciences*. 98(5):2491-2496.

Rotta, G. 2002. (USFS, Plumas National Forest). July 29, 2002, and August 16, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).

Russel, K.R., D.H. Van Lear, and D.C. Guynn. 1999. Prescribed fire effects on herpetofauna: review and management implications. *Wildlife Society Bulletin*. 27:374–384.

Sanders, H. 2005. (USFS, Sierra National Forest). October 28, 2005 telephone conversation with U.S. Fish and Wildlife Service.

Schindler, D.E., R.A. Knapp, and P.R. Leavitt. 2001. Alteration of nutrient cycles and algal production resulting from fish introductions into mountain lakes. *Ecosystems*. 4:308–321.

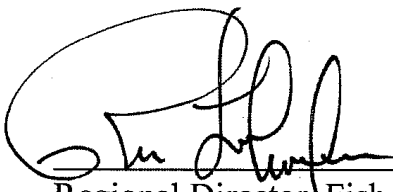
Schoenherr, A.A. 1992. A natural history of California. University of California Press, Berkeley and Los Angeles, California. Pp. 167-227.

- Shotts, E.B. 1984. *Aeromonas*. Pp 49-57. In: G.L. Hoff, F.L. Frye, and E.R. Jacobsen, editors. Diseases of amphibians and reptiles. Plenum Press, New York, New York.
- Sims, L. (USFS, Inyo National Forest). August 8, 2002, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).
- Sparling, D.W, G.M. Fellers, and L.L. McConnell. 2001. Pesticides and amphibian population declines in California, USA. *Environmental Toxicology and Chemistry*. 20:1591–1595.
- Stebbins, R.C. 1951. *Amphibians of western North America*. University of California Press. Berkeley. Pp. 330–345
- Stebbins, R.C. 2003. *A field guide to western reptiles and amphibians*. Houghton Mifflin. Boston.
- Stebbins, R.C., and N.W. Cohen. 1995. *A natural history of amphibians*. Princeton University Press, Princeton, New Jersey. Pp: 225–228, 238–251.
- Stephenson G.R., and L.V. Street. 1978. Bacterial variations in streams from a southwest Idaho rangeland watershed. *Journal of Environmental Quality*. 7(1):150–157.
- Strand, P. 2005. (USFS, Sierra National Forest). October 28, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Taylor, S.K., E.S. Williams, E.T. Thorne, K.W. Mills. 1999. Effects of malathion on disease susceptibility in Woodhouse's toads. *Journal of Wildlife Diseases*. 35:536–541.
- University of California. 1996a. *Rangelands*. In: Sierra Nevada ecosystem project: final report to congress. Volume I, Chapter 7. Center for Water and Wildland Resources, University of California, Davis, California.
- University of California 1996b. *People and resource use*. In: Sierra Nevada ecosystem project: final report to congress. Volume I, Chapter 2. Center for Water and Wildland Resources, University of California, Davis, California.
- USEPA. 1989. *The potential effects of global climate change on the united states*. Report to Congress. USEPA Office of Policy, Planning, and Evaluation.
- USEPA. 1997. *Climate change and California*. State climate change information sheets. USEPA Office of Policy, Planning, and Evaluation. EPA 230-F-97-008e.
- USDA Forest Service. 2001a. *Physical environment in the Sierra Nevada*. In: Sierra Nevada Forest Plan Amendment, Final Environmental Impact Statement. Volume 2.1, Chapter 3, part 2. United States Department of Agriculture. Pacific Southwest Region.

- USDA Forest Service. 2001b. Recreation. In: Sierra Nevada Forest Plan Amendment, Final Environmental Impact Statement. Chapter 3, part 5.6. United States Department of Agriculture. United States Forest Service, Pacific Southwest Region.
- USDA Forest Service. 2004a. Sierra Nevada Forest Plan Amendment, Final Supplemental Environmental Impact Statement, Volume 1.
- USDA Forest Service. 2004b. Sierra Nevada Forest Plan Amendment, Final Supplemental Environmental Impact Statement, Record of Decision, pp. 56.
- USDA Forest Service. 2005. National Forest System Land and Resource Management Planning; Removal of the 2000 Planning Rule. (Federal Register Vol. 70, No. 3, pp 1022–1023).
- USGAO. 1988. Public rangelands: some riparian areas restored but widespread improvement will be slow. Report to Congressional requesters. United States General Accounting Office. GAO/RCED-88-105.
- Vredenburg, V.T. 2000. *Rana muscosa* (mountain yellow-legged frog): egg predation. Herpetological Review, 31(3):170–171.
- Vredenburg, V.T. 2002. (University of California, Berkeley). July 23, 2002, and July 28, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- Vredenburg, V.T. 2004. Reversing introduced species effects: Experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences 101(20):7646–7650.
- Vredenburg, V.T. 2008. (San Francisco State University). February 25, 2008, electronic message to Karuzas, J. (U.S. Fish and Wildlife Service).
- Vredenburg, V.T., G. Fellers, and C. Davidson. 2005. The mountain yellow-legged frog (*Rana muscosa*). In Lannoo, M.J. (Ed.), Status and Conservation of U.S. Amphibians. University of California Press, Berkeley, California, USA, pp. 563–566.
- Vredenburg, V. T., R. Bingham, R. Knapp, J. A. T. Morgan, C. Moritz and D. Wake. 2007. Concordant molecular and phenotypic data delineate new taxonomy and conservation priorities for the endangered mountain yellow-legged frog. Journal of Zoology. 217: 361–374.
- Weldon, C., L.H. duPreez, A.D. Hyatt, R. Muller and R. Spreare. 2004. Origin of the amphibian chytrid fungus. Emerging Infectious Diseases. 10(12):2100–2105.
- Werner, H. 2002. (NPS, National Park Service). August 1, 2002, electronic message to Epanchin, P. (U.S. Fish and Wildlife Service).

- Wilcox, B.A. 1980. Insular ecology and conservation. Pps. 97-117. In: M.E. Soule and B.A. Wilcox (eds.). Conservation biology. Sinauer Associates, Massachusetts.
- Williams, J. 2002. (USFS, Eldorado National Forest). August 12, 2002, October 31, 2002, and November 7, 2002, electronic messages to Epanchin, P. (U.S. Fish and Wildlife Service).
- Williams, J. 2005. (USFS El Dorado National Forest). October 25, 2005 telephone conversation with U.S. Fish and Wildlife Service.
- Wright, A. H., and A. A. Wright. 1949. Handbook of frogs and toads of the United States and Canada. Third edition. Comstock Publishing Associates, Ithaca, New York. xii+640 p.
- Zabik, J.M. and J.N. Seiber. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. Journal of Environmental Quality. 22:80-90
- Zeiner, D.C., W.F. Laudenslayer, and K.E. Meyer (eds.) 1988. California's wildlife. Volume I. Amphibians and reptiles. California Statewide Wildlife Habitat Relations System, California Department of Fish and Game. Sacramento.
- Ziesmer T.C. 1997. Vocal behavior of foothill and mountain yellow legged frogs (*Rana boylei* and *Rana muscosa*). Unpublished MA thesis. California State University, Sonoma, California.
- Zweifel, R.G. 1955. Ecology, distribution, and systematics of frogs of the *Rana boylei* group. University of California Publications in Zoology, 54(4):207-292.
- Zweifel, R.G. 1968. *Rana muscosa* Camp Mountain yellow-legged frog. Catalogue of American Amphibians and Reptiles. 65: 1-2.

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve:  \_\_\_\_\_ Date 6.7.2010  
Regional Director, Fish and Wildlife Service

Concur:  \_\_\_\_\_ Date: October 22, 2010  
ACTING  
Director, Fish and Wildlife Service

Do not concur: \_\_\_\_\_ Date  
Director, Fish and Wildlife Service

Director's Remarks:

Date of annual review: April 14, 2010  
Conducted by: Arnold Roessler

FY 2010, R8 CNOR: Mountain yellow-legged frog, Sierra Nevada Distinct Population Segment